OFFICE OF NAVAL INTELLIGENCE,
GENERAL INFORMATION SERIES, NO. VI.

INFORMATION FROM ABROAD.

64257

RECENT NAVAL PROGRESS.

JUNE, 1887.

NAVY DEPARTMENT,
BUREAU OF NAVIGATION,
OFFICE OF NAVAL INTELLIGENCE,
1887.

WASHINGTON:
GOVERNMENT PRINTING OFFICE.
1887.

TABLE OF CONTENTS.

Page.
Introductory note ... VII
I. Development of modern torpedoes ... 1–44
Spar torpedoes ... 4
Divergent towing torpedoes ... 6
Projectile torpedoes ... 8
Rocket torpedoes ... 10
Automobile fish torpedoes ... 14
Controllable torpedoes ... 30
II. The electric lighting of United States ships of war ... 45–68
The engine ... 51
The dynamo ... 52
The wiring ... 54
The fixtures and lamps ... 59
Search light plant, Atlanta ... 67
III. Systems of forced draft ... 69–113
Closed stokeholds (air-tight fire-rooms) ... 69
Howden's system ... 78
Discussion on the Closed stokehold and Howden's system ... 93
Bureau of Steam Engineering's system ... 111
Wyllie and Morison's system ... 112
Schichau's system ... 113
IV. 8-Inch B. L. R. for the United States Navy ... 114–128
Design ... 115
Material ... 116
Construction ... 120
Sights ... 125
Projectiles ... 125
Powder ... 126
Trial ... 126
V. Notes on the power and disposition of guns ... 129–135
VI. Recent progress in small arms ... 136–151
The Hebler system ... 136
The Remington-Lee magazine rifle, 1887 ... 139
The Austrian Mannlicher magazine rifle ... 140
The German Mauser magazine rifle, M. 71–84 ... 141

Systems utilizing the recoil:

The Maxim recoil repeating rifle ... 146
The Paulson recoil repeating rifle ... 147
The Freddi recoil rifle ... 147
Tabulated data of small arms ... 149
Table of small arms adopted by different nations ... 151
VII. Musketry instruction at home and abroad ... 152–199
Instruction in rifle-firing in the United States Army ... 153
Musketry instruction in the British army ... 161
Musketry instruction in the French army ... 162

Page.
VII. MUSKETRY INSTRUCTION AT HOME AND ABROAD—Continued.
Musketry instruction in the German army 180
Musketry instruction in the Italian army 185
Musketry instruction in the United States Navy 186
Musketry instruction in the British navy 189
Musketry instruction in the French navy 193
Conclusions in regard to musketry instruction 197
VIII. BELTED AND INTERNAL ARMOR 200–211
IX. NAVAL MANOEUVRES, 1886 212–230
French 212
English 222
X. BRITISH ADMIRALTY ANCHOR TRIALS AT THE PORTSMOUTH DOCKYARD 231–234
NOTES ON SHIPS, MACHINERY, ORDNANCE, ARMOR, TORPEDOES, TORPEDO-BOATS, AND OTHER SUBJECTS OF PROFESSIONAL INTEREST 235–279
Austria 274
Chili 279
China 276
Denmark 276
England 243
France 256
Germany 265
Hayti 279
Holland 275
Italy 263
Japan 278
Norway 276
Portugal 273
Russia 267
Spain 269
Sweden 276
Turkey 275
United States 237
United States, notes on steel for new cruisers of 242
SPECIAL REGULATIONS IN FOREIGN NAVIES RELATIVE TO THE CARE AND PRESERVATION OF IRON AND STEEL SHIPS 280–281
English regulations 280
Germany, dockyard and naval regulations 280
French regulations 281
MERCHANT VESSELS FOR WAR PURPOSES 282–288
British Admiralty contract with White Star Company 283
British Admiralty contract with Cunard Company 285
Proposition of Canadian Pacific Railroad Company 286
Postal subsidies of foreign countries—Table 286
French construction bounties 287
Italian subsidies 287
Spanish subsidies 287
Russian subsidies and bounties 287
German subsidies 288
MACHINERY 289–296
Triple-expansion engines 289
Triple-expansion engines. Table I, Naval Engines 293
Triple-expansion engines. Table II, Merchant Engines 294
Compound engines. Table III, Naval Engines 295
Banked fires 296

Page
ORDNANCE 297–316
- Gun steel 297
- United States tests of gun metal 298
- Gun trials 303
- New developments in ordnance 311
- Rapid-fire guns 312
- Revolving-cannon 316

PROJECTILES 317–321
- Armor-piercing 317
- High-explosive 320

ARMOR 322–331
- Contract with Bethlehem Iron Company 322
- Steel armor plates for United States Navy 324
- Armor trials (abroad) 330
- New Cammell compound plate 331

TORPEDOES 332–336
- Torpedo experiments (Resistance) at Portsmouth, England 333
- Torpedo experiments at Toulon 334
- Berdan torpedo 334
- Whitehead torpedo 334
- Howell torpedo 335
- Lay torpedo 335
- Patrick torpedo 335
- Sims-Edison torpedo 335
- Brennan torpedo 335
- Torpedo nets 335

TORPEDO-BOATS 337–342
- General remarks 337
- Austria 337
- China 338
- England 338
- France 338
- Germany 339
- Italy 340
- Japan 340
- Russia 340
- Spain 341
- Turkey 341
- United States 341
- Nordenfelt submarine boat 342

ELECTRIC LIGHTIN, Gplant of the Indomptable (French) 343

INTRODUCTORY NOTE.

In issuing the Annual Publication for 1887, General Information Series No. VI, the Office of Naval Intelligence has followed the plan adopted two years ago of endeavoring to place before the officers of the Navy and others interested in naval matters the latest information obtainable on the most important subjects of current professional interest.

Chapter I contains a historical sketch of the development of the torpedo from 1869 to the present date, and describes all modern submarine weapons.

Chapter II describes the development of the electric lighting of United States ships of war, and is contributed by an officer serving on board the *Atlanta;* it contains information of much practical value to officers taking charge of electric light plants on board of ships of war.

Chapter III describes the different systems of forced draft as used in the United States and English navies, as well as in merchant steamers and torpedo-boats. A large part of this chapter is a reproduction of papers read before the Institute of Naval Architects in England, in 1886, by Mr. Richard Sennett, Engineer-in-Chief to British Admiralty, and Mr. James Howden, and contains matter of great interest to naval officers and engineers at large.

Chapter IV describes the design, construction, and trial of the 8-inch B. L. R. for the United States Navy, the first high-power steel gun of this caliber completed in the United States.

Chapter V indicates the changes which have taken place during the past quarter-century in the development of the efficiency of naval guns by means of improved emplacement and increase of power, and illustrates by diagrams the relative value of gun-fire of typical vessels built during that period.

Chapter VI presents a brief résumé of recent progress in small arms, and describes several forms of magazine and recoil-utilizing rifles adopted, or tried, by the principal nations of the world.

Chapter VII contains a synopsis, with extracts, of the Musketry Instructions in use at home and abroad, both in the naval and land services, indicating the methods of instruction and their application to fire-discipline, together with the systems of rewards offered for proficiency in this most important exercise.

Chapter VIII is a paper upon Belted and Internal Armor read before the Institute of Naval Architects, in April, 1887, by Mr. J. H. Biles, of the firm of J. & G. Thomson, Glasgow, and published, with the accompanying discussion, in *Engineering.* This paper is probably the ablest presentation yet made of the advantages of the system of internal protection for war-ships as compared with that of external or belted armor.

Chapter IX describes the French and English Naval Manœuvres of 1886, with the methods employed for the instruction of the personnel, mobilization, and the exercise of squadrons.

Chapter X presents the results of a competitive trial of anchor carried on at Portsmouth, England, under the direction of the admiralty.

The volume concludes with Notes describing the progress made during the year in the design, construction, and performance of naval vessels, and in the details of their equipment, armament, and machinery, together with a statement of the regulations for the care and preservation of iron ships in foreign navies, and the conditions under which foreign countries secure the services of mercantile auxiliaries (cruisers and transports) in time of war or emergency. These notes have been compiled from administrative and parliamentary reports, budgets, professional journals, and other papers received from manufacturers and inventors.

I.

THE DEVELOPMENT OF MODERN TORPEDOES.*

By Lieut. SEATON SCHROEDER, U. S. N.

The years 1868, 1869, and 1870 are notable as having first produced, respectively, the types of torpedo known as the automobile fish, the towing or divergent, and the controllable. Up to that period there had been no very great improvement over the weapons constructed by Bushnell in 1776, and Fulton in 1801 to 1812. Practically all the elements of modern torpedo warfare had been conceived seventy-five years ago, with the exception of the motive power afforded by the elasticity of steam, air, or other compressed gases of various kinds, and the energy to be derived from the hydrostatic pressures at various depths. Fulton's torpedoes remained prominent until overshadowed by the electric mines of Samuel Colt in 1842, and after that the direction of progress was simply in the perfection of fuzes and in the more practical fitting of Fulton's spar torpedoes.

Interesting accounts of the various phases of submarine warfare may be found in the historical works of King, Barnes, Stotherd, Von Scheliha, Sarrepont, Bradford, and Barber. Suffice it to say here that the legacy left by the civil war in the United States consisted essentially of an imperfect spar torpedo and more or less efficient ground and buoyant mines.

In the several wars of greater or less duration that followed the tremendous strife in the United States little advance was made, and it can only be said that the recurrence of these contests and the crudeness of the methods employed to defend exposed ports stimulated private enterprise. Certainly the success now conceded to one or two remarkable engines of destruction crowns the efforts of their inventors only after years of patient study and experiment, and the expenditure of much money, governments generally holding aloof until the ends in view were nearly within reach.

---

* In the preparation of this article many well-known authors have been consulted, notably Lieutenant-Commander Bradford and Lieutenant Barber, U. S. Navy. Frequent reference has also been made to Patent Office files, various responsible journals, and reports from various sources.

As regards the passive anchored torpedoes there has not been great scope for private capital, and the work of perfecting them has devolved mostly on national laboratories. The importance of the arm had become so obvious that extended programmes of trials were carried on by different governments to ascertain the merits and demerits of various forms of case, systems of ignition, and kinds of charge. It was found that a higher explosive than powder is not only more efficient, *per se*, but, as in the case of gun-cotton, may be less vitally affected by leakage of water. On the other hand, still more violent agents, with proportionately increased destructive radii, require the mines to be placed so far apart, to avoid premature explosion by concussion, that the ground would not be efficiently covered.

In the matter of ignition, the discoveries in electrical science have been such as to practically exclude mechanical or chemical fuzes from consideration, except in special, isolated cases. As compared with them the electric system possesses the advantages of safety in planting and raising; of ability to render and keep them innocuous, but to instantly put them in readiness again when required; of ability to test the condition and efficiency of the circuit upon which the firing depends. Wire-bridge fuzes have generally succeeded the high-tension type, being more simple to manufacture, less liable to deteriorate, better adapted for testing the circuit, and requiring less perfect insulation of the cables. Many different forms have been devised, as also of circuit-closers.

So far as can be ascertained, the present electro-contact type of fuze originated during the Austrian-Italian-Prussian war, the credit for their conception being due to Baron von Ebner; the camera-obscura method of observation, first devised in 1835 by Colt, and put in practice in 1859 for the defense of Venice, was not applicable to the ports of Pola and Lissa, and it was to remedy this defect in 1866 that that talented engineer devised a circuit-closer, to be placed either in the torpedo itself or in a detached buoy. Connection being established with the firing-battery on shore, a vessel coming in contact with the torpedo or buoy would close the circuit and ignite the charge. To provide passage for friendly vessels, a narrow channel was left free from the contact torpedoes, but defended with large electric ground mines to be fired at will. This formed the groundwork of the present system of harbor defense.

The word "mine" is generally applied to such torpedoes as are fixed in a particular place and position and are not capable of aggressive motion. They are known as "ground" and "buoyant" according to their position in the water, and may be further subdivided into "electro-contact" and "observation" mines.

The latter are fired by closing the circuit at the operating station at the moment the enemy's vessel passes over them, the fact of her presence being made known by the camera obscura, by sighting on crossbearings, or by an electric signal sent by the ship touching a circuit-closer.

In the electro-contact mines there are usually two breaks in the circuit, both of which must be closed to fire the charge; one at the mine is closed by the ship, and the other at the shore station by the operator. By this means all danger is avoided in planting and raising them, and safe ingress and egress may be provided friendly vessels.

The cylindrical torpedo case remained in general favor for many years after the American civil war, both for ground and buoyant mines. In liability to break adrift in a tideway, however, it has been found inferior to the turtle shape for ground, and the pear shape for buoyant mines. The turtle shape possesses the further advantages of constituting its own anchor, and of not being easily affected by neighboring explosions. The conical or pear shape carries the centre of the charge nearer to the top and is less easily caught by sweeps than the cylinder. The spherical case, while admittedly the best theoretically for buoyant mines, has until lately been generally put aside on account of difficulty of manufacture. That objection has, however, been largely overcome, the two hemispheres being either permanently joined by welding, or fitted with flanges and bolted together. The latter admits of "nesting" them in store or on shipboard, and obviates the necessity of a loading hole.

One great problem, as yet unsolved, in the present and future development of buoyant mines, is to find a practicable method of keeping them immersed at a constant depth, unaffected by rise and fall of tide. Professional research and private enterprise have led to greater or less approaches to success in various quarters, but so far no plan has apparently been presented that will stand the test of many tides. In this matter no more publicity is invited to methods and results than is apt to attend the production of a perfected implement of war.

While the manufacture of submarine mines and their fittings involves comparatively little cost, and is of a less delicate nature than that of aggressive torpedoes, there is a large outlay, both of skill and money, necessary to render placing and raising them safe and expeditious, and to put their ignition beyond any possibility of failure. Specially designed boats are built by admiralties or war offices for the sole duty of laying or raising them; these need not have any marvelous speed, but must have great handiness of evolution by means of twin screws or otherwise. Their internal fittings also must be with the sole object of handling the mines and their wires.

The question of cables is also one of supreme importance, but which has been satisfactorily solved by several electricians and manufacturers. They must afford perfect insulation to the wires; must be efficiently protected against abrasions on rocks, &c.; must be able to stand a certain amount of strain without breaking; and must be pliable so as to be wound on a drum without injury. They may be single or multiple-cored, the latter being used in connection with "junction boxes," in which the single wires leading to individual mines are connected with the strands of the main cable. One junction box would be needed for each group of mines, and any injury to it would neutralize that entire group.

The operations of countermining, dragging, creeping, &c., have also been made the subject of so much study and brought to such perfection that any group of mines not efficiently protected would soon be exploded or rendered innocuous; and this danger has in turn paved the way to the consideration of a cable system, devised by Lieut. J. W. Graydon, U. S. Navy, for laying and removing them without the use of boats. In brief terms, the buoyant mines are clamped to heavy wire cables that lead from winding-engines across to the opposite shore of the channel, or out seaward to firmly anchored sheaves, and back. The system has many subsidiary elaborations, but those are the main features, the object being to enable the defense to keep the mines out of water until needed, to alter their position so as to place them immediately under the enemy's vessels, and to replace those that may be fired.

In fine, a careful system has to be thought out for each port to be defended, a close relation existing between the positions of the mines, operating stations, and forts, all of which are dependent upon the depth, width, and location of the channel and approaches.

SPAR TORPEDOES.

Up to the year 1868 the only type of aggressive torpedo produced in service (except the simple drifting magazine) was that used with a spar or outrigger. The exploits of Dixon and of Cushing, during the American civil war, engrossed the attention of naval men, and when the leisure times of peace admitted of study and practice, it is natural that the first thought should have been to improve that weapon.

In the consideration of this subject, apart from the form and material of the case and methods of ignition, a vast amount of experiment has been needed to determine the material and section of the outrigger, the best way of attaching the case to it, and the most practical means of keeping it properly immersed when running at speed. For powder charges cast-iron cylindrical cases survived. For the higher explosives, such as gun-cotton, less strength of case is necessary, and sheet-iron has been found well suited, generally galvanized or tinned. Mechanical fuzes were quickly discarded in favor of electric detonators.

Among the earlier experiments in the United States the system was tried of rigging out the spar under water, as in the "Spuyten Duyvil" and "Alarm;"* but that was found generally unsatisfactory, and impossible of application to boats, and all subsequent trials were conducted with above-water gear. The material of the spars successively included wood, cast-iron, wrought-iron, and steel. Secondary spars were also tried and adopted, secured to the primary ones with a view to saving them from the effects of the concussion. It was found that one element that conduced to the rupture of the spar was the weight of water on the middle part, which prevented its rising with the end at the time of the explosion; to correct this, as well as to facilitate the immersion of the torpedo, the heel was raised, the amount of such raising, however, being limited, in ships, by the sweep of gun-fire.

---

* See General Information Series, No. V, pp. 119 and 136.

Different methods of attaching the case to the spar were also found to affect variously the thrust on the socket-plate. The plan of detaching the mine before firing (as in the Wood-Lay) was not revived in practice, although several designs of greater or less value were offered. Among these may be mentioned the *Weeks*, patented in 1882 and 1883. The boom had a casing at the outer end, closed at the top and sides, but open at the bottom. In the hollow of this scoop was placed the torpedo, held by a catch and lug. A contact plate, projecting ahead, disconnected these on being pushed in, allowing the torpedo to drop. A line of a length equal to the desired depth of explosion was secured to the spar and to a firing-pin, operating the latter when tautened.

Boat fittings underwent a number of modifications. In some instances, after rigging out, the heel would be raised so as to depress the point, the pivot remaining stationary; in others the heel would be kept fast and the outer support dropped.

The question of rigging the spars out ahead or on the beam is as much a tactical as a mechanical one. In ships they have come to be used only from the broadside (where used at all). In boats, all rigs have generally been discarded except that ahead; and as thus fitted the spar torpedo has many successes recorded, the more recent of these, in Chinese waters, creating quite a revulsion in favor of a weapon whose blow, while usually of dangerous delivery, was there proven to be of deadly effect.

Berdan.—A novel method of reaching a ship's hull by means of a torpedo has recently been presented by General Berdan, which, while not used in immediate connection with a spar, seems proper to mention in this category, owing to its circumscribed sphere and sureness of delivery. The proposed mode of attack is with special reference to the protection afforded by the steel nettings now being supplied to most battle-ships. On each side of the boat or vessel, at some 50 feet from the bow, is a metal tube, fixed vertically and opening downward, large enough to hold a simple rocket torpedo capable of carrying 200 pounds of dynamite. Each torpedo is connected by a wire rope with a stout bumpkin forward, and, on being discharged downward, swings forward round it as a centre. A long spar projecting ahead, on striking the enemy, reverses the engines and fires the rockets, which then swing under the net and strike the other ship's bottom. It is proposed to fit this apparatus to a boat 150 feet long and of 24 knots speed.

DIVERGENT TOWING TORPEDOES.

The limited radius of action of the spar torpedo and the fact of its being looked upon by many as useless for ships, or at least only serviceable as a defensive weapon, paved the way for the introduction of a towing torpedo, which by its peculiar form and method of towing should be made to diverge and strike an enemy while passing at a certain distance.

The term "towing torpedo" has been frequently deemed synonymous with the "Harvey," that being the name of the originator. Many other patterns have since been made, however, being improvements, or the reverse, on the original. The year 1869 is the one in which this form of offensive torpedo first appeared in serviceable shape. They had apparently been suggested in 1815, and it had been intended to use them in the attack on the United States steamer Housatonic in 1864, but they were first produced by Captain Harvey, R. N., after many years of study and experiment.

Harvey.—His weapon may be described as a rectangular parallelopipedon, with the forward end cut downward with a bevel from the upper surface, and the after end beveled laterally, the beveled edge being on the side next to the towing vessel. The forward beveled edge caused it to point up on being pulled through the water. They were of two shapes, one for the port and one for the starboard side, the difference being in the rear end where the bevel was always on the side next the ship. They were also made of two sizes; the larger was 5 feet long, 6⅛ inches broad, and 20¾ inches deep; the boat size was 3 feet 8 inches long, 5 inches broad, and 18 inches deep.

The cases were made of wood at first, with an interior copper chamber, but Muntz metal was adopted later. They were usually ballasted so as to be about 40 pounds heavy in water, the weight being somewhat increased when high speeds were contemplated.

A system of levers was arranged on the upper side to be pressed in when striking upward, onward, or sidewise, the exploding bolt coming up through a stuffing-box.

A safety key secured in a slot in the bolt was fitted with a line, by which it could be withdrawn when clear of the ship. Experiments were also made with electrical ignition at will, which was afterwards adopted.

For towing, the torpedo was slung by two spans, one from the upper and lower corners of the after end, and a shorter one from the forward end, the junction of the four legs being on a level with the top of the case, the forward span leading back at an angle of 80° to 85° with the near side of the case. Two buoys were usually strung on astern to steady it, and to sustain it at the desired depth when allowed to dive. The tow-ropes were led from a height of 10 to 15 feet or more above the water, and worked from reels fitted with friction brakes. A length of 40 to 50 fathoms was found to give the best command of the torpedo, and the full divergence of 45° was obtained with that length. By slacking the line the torpedo would sink and a subsequent tautening of the rope (by the brakes) would cause it to strike up. This indicates the manner in which it was used, and great skill was required in handling the brakes, for, in conjunction with the buoys, they gave the operator command of the depth at which the enemy was to be struck.

Russia was the first nation to adopt and buy the Harvey torpedo, in 1869. England followed suit in 1870, and after that many countries did the same. The United States, France, Germany, and some others also experimented on their own initiative, the various patterns tried being divisible into two classes, viz, (1) Those that had a buoyant float, to which was attached a magazine which could be permanently carried at the required depth, or attached to the float and dropped at the moment of contact; (2) those (like the Harvey) that were not buoyant, but which were kept at the surface by being towed, diving when the tow-line was slacked.

United States.—In the United States a number of forms were devised. The first, in 1869, had a cylindrical float, pointed forward, 11 feet long by 12 inches in diameter; a long iron bar, carrying the torpedo at the forward end, was suspended at a depth of 10 feet by two flat iron braces. This diverged 35°, but was found to be cumbersome, and was given up. In two other forms, in 1870, the magazine was fitted to be dropped from the float on contact. In 1871 four more were designed, three of which were constructed and tried. One of these belonged to the second class, being 25 pounds heavier than the water displaced, and fitted with two pine buoys.

In 1872 the Harvey was bought and experimented with, after which a "modified Harvey" was designed and built, fitted with a dropping magazine. A mechanical fuze was attached, which was fired by a check-line tautened by the falling of the magazine. Electric fuzes were afterwards fitted, an insulated wire being paid out with the tow-line. This arrangement was quickly superseded by a Danish towing cable made of wire with an insulated copper heart.

Many other forms were proposed by officers of the United States Navy, prominent among which were those of Admiral Porter, and Lieutenants Barber, Converse, and Maynard. All were made with a view to towing on either side, and contained features of greater or less interest and value. In the Maynard a new departure was attempted in having the tow-line lead from under water, the torpedo to tow in an approximately horizontal plane, but, being slightly buoyant, to rise to the surface when not dragged through the water. A couple of cases were made and tried, but did not meet with the success hoped for in the matter of submersion.

All these experiments pointed to the following desiderata for towing torpedoes: They should be long so as not to need buoys; should present small cross-section so as not to offer too much resistance; should present large keel surface to assist divergence; should have a dropping magazine to do away with the difficult task of diving and to insure explosion at the proper depth; should carry 100 pounds of powder or its equivalent; should be fired by electricty, both at will and on contact.

France.—In France exhaustive experiments led to the adoption of three standard models, all of which could be towed from either side by shifting the slings. They differed in form and size of float; one was fitted with a permanently submerged, and the other two with dropping magazines. The method of firing was by electricity, but only on contact, not at will, the current being conveyed by the copper heart of the steel wire towing-cable. In one model, with dropping magazine, the circuit closer was hydrostatic, a sensitive spiral spring being used, which on being compressed by the pressure for which it was set (corresponding to the depth, usually 3 to 4 metres), permitted contact and electrical connection between two platinum points within the spiral.

Mensing.—The Mensing towing torpedo, designed by the German officer of that name, and adopted in Germany, differed from the Harvey in being capable of towing off either quarter. The bow was beveled on both sides, and the stern was square and provided with a rudder. Yoke ropes led through fair-leaders to the bight of the towing spans in such way that the rudder was turned to the side opposite to that of the span that took the strain, thus causing the torpedo to diverge. The firing apparatus was electric, at will or by contact.

Remarks.—Such were the prominent types of a weapon which, during its meteoric career, furnished food for much study and experiment. The original, the Harvey, seemed to suffer by comparison with others in being limited to use from one side or the other, and in requiring great care, dexterity, and judgment in operating it efficiently; and yet those disadvantages seem to have been more than balanced, in the opinion of its English advocates, by superior steadiness and certainty of divergence. Its retention, however, for ten years was eloquent as an exponent of official distrust of the other remarkable engines of war that were beginning to force their way into public notice, and of the acknowledged necessity of having some weapon for attacking below the water-line.

As fitted to ships, towing torpedoes gradually came to be regarded less in the light of an aggressive than of a defensive arm, their presence having presumably a certain deterring effect in a contemplated ramming attack; but even when employed only in that way they were alike dangerous to friends and to enemies. As operated from boats their signal ill-success in the Russo-Turkish war precipitated their final condemnation. They were generally given up in despair some years ago, France alone adhering to them until the spring of 1886, when the manifest destiny of the automobile fish torpedo became apparent.

PROJECTILE TORPEDOES.

Just as sling-stones, arrows, and bullets have successively been recognized as a necessary factor in fighting on land and sea, so of late has the want been felt of a missile in submarine warfare. A bayonet or clubbed musket still finds an occasional use in a pitched battle, and the spar torpedo will retain its place as a similar auxiliary, the sureness of its blow when delivered being a powerful argument for its retension in spite of its limited range. But the developments of the present and immediate future cannot but lead to a weapon perfectly reliable, and whose range will be beyond the length of a boom or tow-line.

The crudest idea and simplest form of underwater missile is the ordinary shot or shell fired out of a gun against a ship's bottom. Like so many elements of torpedo warfare, firing guns under water dates practically from the time of Fulton, who succeeded, in 1814, in piercing a bulkhead equal in strength to a line-of-battle ship's bottom placed 12 to 15 feet from the muzzle. At different times and places the idea was revived and put in practice, but not until comparatively recent times with any tangible results; and among the many who have prepared plans, the only one that has actually produced a weapon is Captain Ericsson.

Mr. Longridge, in England, proposed, in 1868, a muzzle-loading gun passing through a valve-chest in the ship's side or stem. On discharge, when the gun recoiled, a valve would drop and prevent water from entering. His plan called for a monitor provided with one such gun forward and several in broadside. This vessel would ram the enemy, and, at the moment of contact, fire a 9-inch shell into her at a depth of 10 feet; then, by her twin-screws, pivot round and fire her broadside guns at the same depth, and then drop astern, and ranging up on the other side deliver the other broadside, "which would probably be quite sufficient to decide the contest."

Ericsson.—Ericsson's apparatus, produced in perfected form in 1881, was a breech-loading smooth-bore gun, the muzzle being secured water tight to the vessel's bow, which thus took up the effort of recoil. An exterior water-tight valve was fitted to close the aperture before and during the loading, being worked by an elbow lever and a rod passing in through a stuffing-box. Within that a temporary valve was placed, being pushed forward from the breech until the spring-catches in its periphery caught in an interior rabbet in the gun-wall This valve, shot away at each discharge, was made of wood, with a central hole closed by soft material, the object being to avoid danger of premature explosion when the firing-pin of the projectile struck it. The projectile occupied nearly the entire length of the gun, there being immediately in rear of it a piston, and behind that a powder charge occupying only a small portion of the chamber.

The projectile was 25½ feet long by 16 inches in diameter, cylindrical in the middle with long pointed ends. The one experimented with was made of wood, the conical tail-piece having an iron rod running through a tightly fitting perforation in the axis to give it strength to resist the crushing effort produced by the discharge. The total weight was made nearly equal to its displacement, the buoyancy being about 60 pounds. The charge chamber was in the forward cone, which was blunter than the rear, and fitted with a projecting firing-pin, which, by having to be driven in against a powerful spring, would not act by striking the frangible muzzle-valve nor from the pressure of water in its flight. The service torpedo was of steel, and weighed 1,500 pounds, including 300 pounds of explosive. Four radial wings on the tail end served to centre it in the gun.

A series of experiments showed that 12 pounds of powder would fire it at such velocity as to run 300 feet in three seconds. At the trials before a United States naval board in 1881 it was not very successful; in neither of the two shots fired did it strike the target, (which was 25 feet wide, 11 feet deep, 285 feet away,) but touched bottom in 15 feet of water, the gun being submerged 7 feet. The projectile was afterwards fitted with a horizontal rudder set at a slight angle to prevent its diving.

The vessel in which the gun was fitted was the Destroyer, which may be briefly described as being intended to fight bows on, having great turning power and a heavy inclined armor bulkhead forward.

One of the principal difficulties was that there was no means of determining if the gun was level, and if it were not so the only means of correcting it was by trimming the ship. Of course that would preclude any possibility of accuracy when there was the slightest motion on. The projectile was considered able to pierce any of the ordinary forms of torpedo defense, and smaller than any other movable torpedo carrying the same weight of explosive. No trials were made underway, nor any except with the "dummy," *i. e.*, without explosive charge; but it seemed to promise well, and the Board reported that it was a most formidable weapon, and, within a limited range, superior to any known form of torpedo.

The field of trial has of late been transferred to England, where a recent experiment resulted in the explosion of the projectile in the gun, another detonator having apparently been substituted for Ericsson's. While it is admitted that a delayed-action detonator could be used, as in the Whitehead torpedo, further experiment is said to have been declined.

ROCKET TORPEDOES.

The density of water being about 800 times that of air, there seems to be a natural limit to the range attainable by a mere projectile in water. An appreciation of this has led to attempts being made in the direction of providing torpedoes with a motive power in themselves, and the history of such efforts really antedates that of firing shot under the surface, the means employed being the combustion of a gunpowder composition of greater or less strength, the kick of the gases against the water furnishing the propelling effort.

The history would begin in 1730, and to bring it up to comparatively modern date would include many names, of which Désaguliers, Paixhans, La Villette, Joshua Blair, and Montgéry seem to be the most prominent.

Hunt.—In 1862 Major Hunt, U. S. Army, devised rockets 2 to 3 feet long, which he proposed to fire from a submerged 11-inch Dahlgren gun. He afterwards used a 12-inch bronze tube instead, fitted with a ball-and-socket joint in the side of a caisson, and provided with a slide valve near each end. The outer valve being closed to exclude the water, the inner was opened and the projectile put in, the inner valve shut and the outer opened; the composition was then ignited by a Gomez fuze. To steady the flight some were fitted with a wooden jacket grooved spirally, so that the water would assist in maintaining a rotary motion imparted by the issuing of the gases through side ports. They were propelled in this way several hundred feet, but the direction was unreliable in both horizontal and vertical planes, and an accident resulting in the death of the major and his assistant brought the system into temporary disrepute.

Barber.—Some years then passed without much attention being apparently paid to this subject; but in 1873, a plan was submitted by Lieutenant Barber, U. S. Navy, which combined to a remarkable degree the various features so essential in securing accuracy of flight. The various elements entering into the problem are best stated by that officer in the following words:

> It should be remembered that these attempts [to make the rocket a reliable and accurate weapon] have been confined to the air, where two sources of error were continually involved, viz: A change in the weight of the projectile after it had commenced its flight, and a change in the position of the centre of gravity; but when we enter the water as a field for experiment, the medium itself furnishes a material for keeping the weight constant and the position of the centre of gravity unaltered, it being merely a problem to discover the right method of utilizing that material. Supposing this to be done, the next requirement is to obtain accuracy without resorting to diving or steering rudders, and the rotary motion at once suggests itself as being the simple method by which this result is obtained with an elongated projectile in air. The consideration of rifled projectiles in the air, however, and the constant tendency of gravity to bring them to the earth, suggests that in water we can free the projectile from even the action of gravity by constructing it of the same weight as an equal bulk of water and making the centre of gravity coincident with the centre of figure.

The rocket proposed by Lieutenant Barber was 7 feet long and 12 inches in diameter. The outer case was of oak, rifled on the Whitworth system. The composition tube, which did not fill this shell, was centred in it by a spiral tube made of light metal and capable of holding 52 pounds of sea-water, there being an opening at the forward end of such size as to admit 51 pounds of water in the time that the 51 pounds of composition would take to burn at a given depth (and pressure). The tail-piece was pierced by six holes cut in the prolongation of the exterior (rifled) faces, so as to assist the rotation. A needle cartridge was also placed in the centre of the rear end, covered by a disk holding the needle, which would be crushed in by the blast of discharge whether by compressed air or powder. During the flight of the rocket water enters by the gate near the front end, and, in consequence of the rotary motion imparted to the shell by its twisted faces, is thrown by centrifugal force to the side of the spiral tube farthest from the axis, and will pass aft on that side to the rear of the rocket, where it is wanted to make good the lost weight of the burnt composition; the air, in the mean time passes forward along the inner side of the spiral and out through a fine tube too small for water to enter.

Weir.—The plan submitted by Mr. Robert Weir in 1874 was for a rocket of circular cross-section 7 feet 7 inches long, by 12 inches in diameter, having the same specific gravity as water, and arranged so that the weight of composition burned would be replaced by water allowed to enter. The total weight was to be 245 pounds, of which 74 would be explosive and 78 rocket composition. The rear part was tapered, a loose wooden sabot filling up the shape, which would fall away after clearing the gun. The holes for the exit of the gases were at the rear end, some being for rotation and one for direct propulsion; the latter was the largest, and directed the stream against spiral vanes to assist the rotation. Experimental models about 2 feet long, fired from 4 feet under water, attained a speed of 14 feet per second for 63 feet (the distance of the target), and struck at 5 to 7 inches below the 4-foot mark. The inventor accepted the theory that as the speed increased (owing to enlarged fire area produced by the burning away of the composition), the tendency of the projectile would be to rise toward the surface, that being the place of least resistance in the fluid, and he constructed the weapon so that while the specific gravity of the whole remained the same, that of the rear end would decrease, thereby counteracting the tendency to rise by changing the apparent line of direction downward.

Burdett.—In a plan suggested by Gunner Burdett, U. S. Navy, in 1874, it was proposed to preserve the given depth by a diving rudder controlled by a cylinder and piston, worked by the pressure of the water. Another essential feature was the ignition of the composition at the forward end, the gas being directed to the rear by means of curved shields.

Weeks.—The more recent types of rocket torpedo that have been produced are surface weapons. Of these the Weeks was quite extensively tried in the United States in 1884. It was constructed mainly of sheet-metal, and was of triangular cross-section, apex down, so that the ratio of displacement would decrease rapidly with the decrease of immersion brought about by the consumption of the composition. Two long tail-pieces with fixed rudders extended astern, to assist in preserving direction, and also by their dead weight (when lifted out of water) to counteract the tendency to bury forward. To this same end, the bow, which was wedge-shaped, and which carried the magazine, had an air-chamber upon it, to lift by its buoyancy when plunging. In the cut-water was a firing-pin, to act by percussion; and it was provided in the patent that in case of attacking a vessel protected by nets, this pin should carry a transverse plate large enough to insure engaging the meshes, thus compressing the spring and releasing the trigger.

In some of the patterns built the composition was placed in two tubes, arranged one above the other, or end to end, and separated by a fusible or movable diaphram. The composition was bored out to a certain distance, eccentrically with the axis, but on a line with the aperture leading to the second chamber, so that the material in the latter would be reached by the flame and ignited before the former was quite exhausted. At the forward end of the combustion chamber was a magazine by which the float would be blown up at the end of the course in case of missing the mark.

No tube or gun was used for starting the Weeks torpedo; it was simply dropped from davits, and the composition ignited by an electric fuze. The gear not being capable of train, the pointing had to be done by the helm of the vessel.

At the trials in 1884 it developed a speed of 23 to 45 knots an hour, with a range varying between 300 and 850 feet. It was found to possess the advantages of simplicity and cheapness, but to be fatally defective in accuracy and range; its speed also, while great, was very variable, and the effect of the magazine exploding at the surface was more or less doubtful. For these and other reasons it did not receive a favorable report.

Chambers.—Prominent among other recent designs is that patented in 1884 and 1885, by Ensign W. I. Chambers, U. S. Navy. This is a compact surface float, but with a dropping magazine, and adapted to receive its first impulse from a gun or tube. The case is cylindrical, with tapered ends, and made of wood, cork, or other buoyant material, sheathed in thin metal. The magazine is contained in a recess in the lower part of the middle body, and, by its weight in that position, imparts stability in the water; it is sustained by lugs and hooks, the latter being freed by backward motion on impact; the bars that then control it are jointed spring bars, which give it an impetus downward and cause it to swing forward, the explosion being brought about by either a percussion or a time fuze.

An important and novel feature in this weapon is the burning of the motive composition from the front ends of a number of small tubes, each made up of short lengths of piping screwed together, arranged longitudinally round a larger central one and discharging their gases through it to the rear of the shell. It is claimed that in packing short lengths of composition under the same conditions and with the same pressure, the densities will be quite uniform at corresponding points in the several lengths, and by arranging these so as to "break joints," great aggregate uniformity will be obtained in their simultaneous combustion. Slight unevennesses will also be nullified by the air cushion obtained by the gases being generated at the front ends and exhausting through the long central tube.

Further details of this torpedo comprise a sabot (to fit the discharging gun), the stem of which lies normally in the central exit tube for the gases. Projecting pins in its periphery engaged in lugs or holes in one or more longitudinal bars contained normally within the shell, but which, when drawn out, constitute tail-pieces. The specifications provide that these may be fitted with movable rudders, which may be set at an angle to counteract the effect of winds or currents.

The operation of the torpedo is as follows: It is ejected from a tube, above or below water, by a charge of powder. The flame, penetrating through two perforations in the sabot, ignites the time fuze at the rear end of the magazine and the rocket composition. The gases from the latter drive out the sabot, which pulls out with it the tail bars, from which it is free to unhook when its stem clears the central tube. This leaves the exit free for the gases to escape and act against the water or air. The hooks that sustain the magazine are on the bands round the group of composition tubes, and these, forming virtually one rod, are pushed back on impact, disengaging the magazine, which then drops and swings forward. In case of missing the target, the time fuze acts.

The inventor of this torpedo claims that its aim and accuracy are assured by its being ejected from a tube and by the tail with which it is provided; that its range is greater than that of other automobile torpedoes; that its speed gradually increases up to the moment of impact; and that its safety, simplicity, lightness, and cheapness recommend it for extensive use on shipboard.

Remarks.—Simple rocket or projectile torpedoes possess many valuable qualities, but, as naval weapons, are open to some objections. Those that remain on the surface are exposed to no disturbing causes in a vertical plane, but are liable to rank horizontal deviations. Those that are projected under water, on the contrary, may possibly be made to go in a straight line, but the horizontality of that straight line is dependent upon that of the discharging tube—an impossible feature on shipboard. On the shore this impossibility does not obtain, and, in view of their extreme cheapness and simplicity of manufacture and manipulation, a contemplation of the great number that could be sent against an attacking vessel is full of significance regarding possible future defensive operations.

AUTOMOBILE FISH TORPEDOES.

The automobile fish torpedo, which has stirred naval tacticians more profoundly than any weapon ever produced, is the outcome of private thought and enterprise. The objects that it has been intended to attain are: Constant submersion to a given depth while in motion; ability to propel itself along a straight course; ability to carry a large charge of explosive matter, with sure but safe means of ignition; ability to attain a speed and travel a distance that would make it a formidable weapon.

Whitehead.—Strictly speaking, the "fish" is the first really aggressive type of torpedo known in practice; and the first of its kind was the Whitehead, so called from the name of the inventor, to whom belongs the credit of first utilizing the hydrostatic pressure to regulate the immersion. And while the Whitehead has undergone, since its first inception and creation, many changes and improvements wrought by different hands, including those of its inventor, it is a matter of wonder that the first attempt to produce a self-sustaining, self-propelling subaqueous missile should have attained the success that characterized its first appearance.

It was apparently in 1864 that Mr. Whitehead's attention was first directed in this channel, it being suggested to him by Captain Luppis, of the Austrian navy, to build a surface-floating vessel that should be propelled against an enemy without carrying a crew. Luppis is said to have become impressed with the importance of the idea from some plans that had come into his possession on the death of a marine artillery officer. In the original idea the power was to be generated in the boat when needed, either steam or hot air being supplied by a boiler. In one bound Whitehead sprang far ahead of this; he generated his power beforehand and stowed it in tanks in the shape of compressed air, which, on being released, was admitted to the engine and revolved the screw. The power of running under water was but a corollary to that. Four years were passed in study and labor before the implement could be offered for sale, and it is even said, also, that the expense incurred amounted to some $200,000.

Instead of resorting to patent rights with their protection and dangers, Mr. Whitehead has maintained a close reserve concerning the apparatus for regulating the submersion, only broken under the terms of advantageous sales to different countries.

The early form of the "Luppis-Whitehead" machine, as it was known in 1867, was more that of a dolphin, in the forward part, than of a spindle of revolution, which it has since assumed. It was constructed of wrought-iron, and fitted with vertical and horizontal blades or fins, the latter being actuated by what was, and is still known as "the secret," their function being to deflect it upward or downward when below or above the plane along which it was intended to move. The motive power seems to have been applied through a rotary engine, from the accounts of which Major Daudenard evolved a drawing which may be correct, and which, at all events, fulfills the conditions attributed to it by Ericsson, of being extremely wasteful of power. This drawing shows a cylinder placed eccentrically within another, and in contact with its inner surface, actuated and made to revolve round the axis of the outer by compressed air admitted through a specially contrived valve opening in the circumference of the latter.

A sliding plate next to the valve moved in and out at each revolution, always remaining in contact with the inner cylinder and compelling the air to act always on one side and in one direction. The propeller was on the central shaft of the outer cylinder, to which the inner was keyed eccentrically.

By 1868 the torpedo had attained the fusiform shape that it presents now and was propelled by a four-bladed screw, the machinery being set in motion at the time of discharge by withdrawing a pin (by a cord), and thus opening communication between the air chamber and engine. Guide-rods were also attached to the shell to center it in the discharging-tube. The magazine was in the forward cone, which was detachable, and was exploded on contact by horizontal and vertical triggers, and by the movable point of the case. The inventor claimed that it could be set to run at any depth from 0 to 25 feet; to run any distance, and then sink, rise, and explode, or be made incapable of exploding, as determined beforehand.

At the time of working out this torpedo Mr. Whitehead was the superintendent of a large iron works in Fiume, so it was but natural that the Austrian Government should be the first to inaugurate experiment, and the first official trials ever made with an automobile torpedo were before a naval commission at Fiume in 1868. The machines presented were of two sizes; one was 11 feet 7 inches long, 14 inches in diameter, weighed 346 pounds, and carried 40 pounds of gun-cotton (for which an equal weight of junk was substituted in the experiments). The larger, called the "normal" torpedo, carrying 60 pounds of explosive, was 14 feet 1 inch long, 16 inches in diameter, and weighed 650 pounds.

The plan of the inventor was to discharge them from a tube 12 feet under water, that being the depth for which the mechanism was "set." But the gunboat Gemse, which was furnished for the purpose, drew only 7½ feet of water forward, and a submersion of 3 feet was all that could be obtained. The discharging tube was built in the forward deadwood, dipping slightly downward. The outer end was provided with a conical door (apex out), worked by means of a strap-hinge and lanyard. Inside the deadwood was a gate, worked vertically by means of gearing. A third water-tight door closed the inner end. Compressed air being used to eject as well as propel the torpedoes, a reservoir was suitably located near by communicating with the rear end of the tube. The torpedo being inserted, the tube was flooded by a branch pipe from a Kingston valve; the vertical valve could then be opened, and also the conical protective cap outside. By opening communication with the air-reservoir the torpedo was thrown out with considerable velocity, its engine being started at the same time by withdrawing the pin.

The mechanism having been arranged with the expectation of projecting it at the depth which it was intended to maintain, it was a severe test to start it at a depth of only 3 feet, and one which it did not stand, the oscillations in a vertical plane being so great that its path varied between 0 and 40 feet submersion. Of fifty-four shots only eight caught in the target-net, which was 690 yards off, 208 feet long, about 18 feet deep, and hung with the upper edge 6 feet under water. The mean speed was 9.43 feet per second, or 5.66 knots an hour.

As usual the severeness of the test was productive of improvement, as the inventor set to work to remedy the defect, and, at a second trial three weeks later, the weapon kept a more level course, and recorded 50 per cent. of hits in thirty shots. The speed was also one-fifth of a knot greater.

Experiments were then made with the Gemse under way, going 7 knots. The torpedo was ejected without difficulty, but the ship's engine had to be eased immediately or the helm put over to avoid running it down. With stern board on, it was found that the eddy did not influence the direction. With a moving target, the Gemse also being under way, it was found to require great practice and accuracy of eye and judgment to hit.

The larger (normal) torpedo, projected from a tube placed at the depth of 14 feet, for which it was set to run, attained a mean speed of 6.7 knots.

In general these trials showed that the direction was fairly maintained in still water up to about 650 yards, but after that it became uncertain in consequence of diminished speed. The commission gave as their opinion:

(1) The exploding power of 40 pounds of gun-cotton is quite sufficient to sink any ship.

(2) The certainty of hitting is as great as can be expected from such an arm.

(3) The firing apparatus never fails.

(4) The velocity is indeed not great enough to catch a fast ship in chase; but it is quite sufficient for the defense of harbor entrances and for attack of ships at anchor; and, as ramming is now the principal mode of attack in naval battles, and they therefore become nothing short of a *mêlée*, torpedoes can even then be employed with advantage.

The vote was unanimous in favor of acquiring the secret.

In the light of the subsequent almost wonderful development of this weapon, the report seems strangely flattering, and some parts of it were possibly made with recollections of Lissa fresh in mind. Supply must equal demand, and demand stimulates production. If in the first trials it had been possible to place the Gemse's tube 12 feet under water, the mechanism for regulating the immersion might have remained faulty for some time, whereas, when pushed, Whitehead flattened the trajectory immediately. Fortunately the purchase of the secret and right to manufacture by England, France, and other countries, created a competition which helped to prevent any possible stagnation arising from so favorable an expression of opinion.

The United States is the only prominent maritime country that has not bought the Whitehead, but the study of the problem was none the less pushed there some years ago. In 1869 a fish-torpedo was commenced at the Naval Torpedo Station, and in the two succeeding years was perfected until equal in some respects to the Fiume model at that time. It was cigar-shaped, about 12 feet long, with a composition shell three-sixteenths inch thick. The total weight (including compressed air) was 480 pounds, a little less than its displacement. At first the submersion was regulated by the admission and ejection of water, thus effecting the weight and causing it to sink or rise. This plan was given up, however, and the result effected by diving fins, connected by rods and bell-cranks, with a hydrostatic bellows secured water tight over an aperture in the bottom; the pressure at the required depth, by inflating the bellows (against a spring), would move the fins, they being so set that, for an inflation of the bellows corresponding to the pressure due to the desired depth, they would be parallel to the axis of the torpedo, and for greater or less pressures would deflect it upward or downward. The adjustment for different depths was easily effected by altering the length of the rudder rods. The engine, designed by Lieutenant Converse, was constructed on the "diamond" principle, with two cylinders, and exhausted through the hollow shaft, the propeller being single and four-bladed, two of the blades being abaft and at right angles to the other two. The submersion apparatus worked perfectly, but the speed was deemed insufficient, the diamond engine not achieving the success that has since attended it when provided with a larger number of cylinders.

Rendel.—Alteration of the buoyancy to preserve a constant submergence was also resorted to in the Rendel torpedo, patented in England in 1871, an apparatus being devised analogous to the swimming bladder of a fish. In general terms a hydrostatic bellows was charged with compressed air until the pressure was equal to that due to the desired depth. The elastic diaphragm of this bellows connected by a rod with a valve which allowed communication between an air-bag (the swimming bladder) and the reservoir of compressed air used for propulsion. Before starting, the bladder was empty and kept collapsed by a spring; the torpedo being heavier than the water displaced, would immediately descend; on reaching the desired depth the diaphragm of the bellows, distended at starting, would have been pushed in far enough to open the valve admitting air to the bladder, which by expanding would increase the displacement, and consequently the buoyancy, the weight remaining the same. Should the torpedo then rise above the proper depth, the diaphragm distending again would close the air valve and open communication between the air-bag and the sea. One apparatus of this kind was placed near each end of the torpedo, with a view to keeping the axis horizontal.

In a later design an immense improvement was effected by invoking the aid of pendulums to assist in preserving horizontality of axis. The torpedo was sustained at the required depth in the same way as in the previous model, by a central bellows and bladder, but in addition there was at each end a separate smaller bladder with a three-way cock in the pipe leading from the air flask. This three-way cock was actuated by a pendulum, which closed it when the torpedo was horizontal; on swinging one way it would admit air to the bladder, inflating it, and causing that end to rise; on swinging the other way it would open communication between the bladder and the sea, when the air would be ejected and the buoyancy of that end decreased. The valves worked in opposite ways at the two ends; if the nose of the torpedo were to dip the forward bladder would be inflated and the after one collapsed, and *vice versa.*

Mr. Rendel's patent also provided for a spiral fin on the outside of the shell to give it a rotary motion to assist in preserving direction. In case of applying this to the second model, the pendulums would hang from a sleeve loose upon a spindle between two collars, which, by the inclination of the pendulum, would be pushed one way or the other, and operate the three-way cock by means of a rod.

The propulsion was by means of one propeller, or two revolving in opposite directions, or by direct thrust of a folding cross-head, after the fashion of a duck's foot.

Whitehead, continued.—In a design produced at Newport, R. I., in 1874 the same general principle was adhered to for the diving gear as in the model of 1871, but the method of application was different. In this one the rudder was at the tail end, the rod passing in through the hollow propeller-shaft. A hydro-pneumatic cylinder was placed concentrically on the latter, the piston of which, under the pressure of the water outside, was pushed forward against the resisting air cushion within; a pin on the rudder rod, coming through a longitudinal slot in the hollow shaft, engaged in a groove in the piston edge, and by it the rudder rod was moved back and forth, actuating the diving rudder, to which it was connected by rack and gears. The apparatus was capable of adjustment for 8, 12, and 16 feet depth by changing the position of the piston in the cylinder, thus varying the air-cushion space.

While this torpedo was not carried beyond the plan stage, a mention of it seems proper, more especially as the experiments carried on at that time by Lieut. F. M. Barber to determine the power actually expended in forcing a totally submerged spindle through the water were of crucial interest, not only from a purely scientific point of view, but particularly in the study of the interesting problem of torpedo propulsion. The shell of the Station Fish torpedo, set for 8 feet depth, was towed at different speeds, and the resistances plotted as ordinates, the abscissæ being the speed in knots. The resulting curve had a double flexure before reaching a speed of 8 knots, indicating that the supposed laws of resistance, as bearing any definite ratio to speed, were erroneous as applied to wholly submerged bodies; it appeared then that the resistances to be overcome at speeds exceeding 8 or 10 knots are less than anticipated, and that after once getting over the point of contrary flexure in the curve the higher velocities are more easily attainable. This discovery might well account for the suddenness with which Whitehead, after laboring for several years to attain a 10-knot speed, produced a torpedo very little larger than its predecessors, but which made 17 knots for 600 feet; this was in response to a demand by the German Government for one that should make 15 knots for 500 feet.

From that time on the speed and range of the Whitehead increased under the competition of different private and national laboratories. Apart from the advantage *per se* of reaching the target quickly, speed was found to increase the resistance to deflection in a horizontal plane; and it was found practicable, and usually desirable, to raise to the utmost the initial velocity even at the cost of materially shortening the range.

In 1874 the status of performance was this: A starting speed of 18 knots was maintained for 600 feet, the total range then being 2,600 feet at reduced rate; with an initial speed of 15 knots, rate constant for 1,300 feet, and range 4,000 feet; starting at 12 knots, rate constant for 3,500 feet, total range 5,000 feet. The inventor admitted that the accuracy rapidly diminished as the speed decreased below 8 knots.

In 1876, 20 knots was realized in a number built for the Scandinavian countries, 18 knots having been guaranteed, but a premium having been offered for any excess.

It is a noticeable fact that what would seem the most difficult problem, namely, that of regulating the submersion, was quickly solved satisfactorily, and that the great stumbling block for a while was the application of motive power. The Luppis-Whitehead rotary, a Barker's mill, a "diamond," and a compound oscillating engine were successively tried by different experimenters, the latter immediately preceding the three-cylinder Brotherhood, which has since remained in favor. In this engine the trunk cylinders, placed radially about the shaft and common crank-pin, take air only on the back side and exhaust directly through the crank pit and hollow shaft. It is peculiarly adaptable to the propulsion of fish torpedoes from its ability to perform well whether the reducing valve be set for high speed or long range.

Early in the history of his weapon, Whitehead realized that to keep a straight course it was necessary for the torpedo to maintain an upright position in the water, as otherwise the effort of the horizontal diving rudder would have a horizontal component tending to deflect it from the initial path. It was also found that the reaction of the propeller caused the torpedo to roll the opposite way. To correct this the edges of the vertical fins were bent to produce a contrary effort. The amount of listing and lateral deviation, due to the action of the propeller, being proportional to the speed of revolution, it was evidently necessary that that should be constant, which was easily effected by a reducing valve. It then remained to make the helm angle correspond with the prearranged speed—a delicate operation and one requiring repeated trials. Moreover, when the compressed air had been used to such an extent that the pressure in the flask fell below the tension of the reducing valve spring, the speed diminished and the counteracting effect of the rudder exceeded the tendency to deviate; it was therefore possible to regulate the course only during the first rapid stage of its flight.

This militated against the excellence of the weapon, and the idea of having two screws revolving in opposite directions, suggested by Ericsson and first introduced at Woolwich, was a most important modification. Whitehead promptly adopted the plan, the screws being two-bladed, one abaft the other on the same line of shafting. While this corrective did not wholly eliminate the evil, it reduced it to manageable limits.

Many other mechanical improvements were added by the various private and national competitors. While it was still in its infancy the starting of the engine was effected automatically by a trigger taking against a stud in the tube during ejection. To prevent premature explosion a safety bolt is interposed, which is automatically withdrawn after a certain number of revolutions of the propeller. The violence of oscillations in a vertical plane has also been diminished by causing the submersion mechanism to impart to the rudder a rapid series of slight movements instead of one broad stroke.

Since the adoption ot the Brotherhood engine and the attainment of a speed that carried the resistance curve beyond the point of contrary flexure, the farther increase in speed has been by small increments due to perfected workmanship. Flasks have been so perfected as to stand pressures of 100 and 105 atmospheres. Some care is needed in filling them, particularly to keep the temperature down, as otherwise when chilled by being launched the pressure would fall. Both velocity and range are affected in this way by the temperature of the water in which the torpedo is navigating. With the same initial charge better actual results are said to have been obtained in a warm than in a cold medium.

As now perfected these torpedoes are made of steel or bronze, from 10 to 19 feet in length, according to service requirements, carry from 40 to 105 pounds of gun-cotton, and attain speeds up to 27 miles for moderate distances. The weight of the largest is in the neighborhood of 800 pounds. A more usual size is about 14½ feet long, different models weighing between 500 and 600 pounds. The larger size, besides carrying a heavier charge, is apt to be more accurate in flight, owing to its greater length, which is the only element influencing the horizontal stiffness of trajectory. On the other hand the smaller ones are correspondingly easier to handle, and specially adapted for boat work.

Five metres is the maximum submersion, but that is seldom reached in practice.

As is usual with such inventions the work expected and required of these weapons has varied for mechanical and tactical reasons. In 1868, with a speed of 5 to 6 knots, the accuracy was deemed as great as could be expected, and the speed sufficient for harbor defense. In 1873, when the velocity had reached 10 knots, 2,000 feet was considered the maximum efficient range of action. As the speed rose quickly to 18 and 20, and gradually to 26 and 27 knots for short distances, national purchasers inclined to long ranges; but as the speed of ships increased, and the mechanical and tactical qualities of the weapon became better known, certainty at a moderate range came to be preferred to uncertainty at greater distance, and the tendency now is to demand the highest attainable speed for the first 200 yards.

Among other vital questions that have arisen is that of discharging the Whitehead torpedo. An air impulse was first proposed for ships and submarine batteries, and a simple cage, from which it would propel itself, was provided for boats, hanging under them, the engines being started by withdrawing the pin. Side suspension fittings were also tried in boats, and afterwards Yarrow's steam impulse. Air has again been received into favor, however, its chief competitor being powder. The latter has been tried with success, and is used by several admiralties, notably that of France. Experiments with it were first begun in 1879 by the School of Pyrotechny at Toulon, a wooden dummy being used of the same form and weight as a 14½-foot Whitehead. In 1882 the system was tried with torpedoes having the air flasks charged and explosive in place, and, being found safe as well as convenient, was officially adopted. For the 19-foot torpedo the cartridge contains from 6 to 10½ ounces of powder, according to the height of the tube above water; for the 14½-foot, 3½ to 4½ ounces are found to be sufficient. The firing is usually done by electricity, but a system has also been introduced of firing by percussion primer. The merits of powder ejection consist in the simplicity of its use and in obviating the necessity of having air-compressing machinery at hand (in boats). On the other hand it is contended that it fouls the tube; that its sudden action is hard on the delicate mechanism of the tail of the torpedo; that it causes variations in the temperature, which will cause variations in the windage of the torpedo in the gun and affect the velocity of ejection; and that accumulators are necessary under any circumstances to make good the unavoidable leakage in flasks that have been charged for some time. In the definite settlement of this question it may be remembered that the action of powder may be controlled more perfectly than almost any known source of power; that it is not found to injure the mechanism, and that if it did, the tail of the torpedo could easily be shielded; and that since the adoption of double throttles the leakage of flasks is much less than heretofore.

The practice is different in different services regarding the dip of the tubes, the angles varying from 0° to 9° with the horizontal. The elements to be considered are the motion of the vessel in a sea-way and the diving of the torpedo; rolling or pitching motion would materially alter the angle of projection, even possibly making the torpedo strike the water tail first; while, on the other hand, too great an angle would cause it to dive so deep as to require a long time to flatten the trajectory.

Schwartzkopff.—The Schwartzkopff torpedo is the outcome of Germany's purchase of Whitehead's secret and right to manufacture, being the production, under governmental supervision, of the Berlin Machine Building Stock Company, formerly L. Schwartzkopff. This factory is the one private rival of that in Fiume, and has added its quota to the amount of investigation devoted to the solution of the problem. The shell, air-chamber, and working parts of the Schwartzkopff are made of a phosphor bronze, the composition of which is kept secret. Other mechanical improvements are also due to this firm. The general plan, however, is still practically that of the Whitehead, and this name, when applied, has been intended to include the entire family, without disparagement to the independent work at Berlin, Woolwich, Indret, Venice, Cronstadt, and other ports.

The one inherent defect (if so harsh a term can be applied) in the Whitehead torpedo is the lack of directive force in a horizontal plane. Owing to its length it has a tendency to go straight if not beset by disturbing forces, much in the same way as an arrow, but its trajectory is not stiffened in any way, like, for instance, that of the rifle ball.

Howell.—This essential quality has been supplied by Captain Howell, U. S. Navy, in the weapon bearing his name. Recognizing the power contained in the gyroscope, this officer began, in 1870, to experiment and develop the best means of utilizing it for the guidance of submarine weapons. At first he placed the axis of a fly-wheel in the longitudinal axis of the torpedo, and, in the first plan brought forward, this wheel was in the shape of a cylinder on the propeller shaft. The cylinder performed two other functions: it contained the explosive, and its momentum, on being caused to revolve, furnished the propelling power. The shell was cylindrical, with conical ends, and a screw was placed at each end of the shaft running through the axis. The launching apparatus consisted of a steam cylinder and long piston-rod; and a little set of machinery actuating a geared wheel on the after end of the propeller shaft gave it and the cylinder a rotary motion before ejection.

The first change introduced in this original plan was to make the fly-wheel of solid iron, and to place it with the axis athwartships, the explosive being packed in the forward cone. These features have since been retained, and in the further development of the weapon the changes have been in improved application of the motive power and in the fitting of horizontal and vertical steering gears. For the propulsion the forward propeller was abolished and twin screws placed aft, being driven by belting from the fly-wheel axis; then the propeller shafts were geared direct to the fly-wheel axis; then a centrifugal pump was substituted for propellers; then reciprocating fans on the principle of a fish's tail; finally, two screws again. The methods of spinning up the fly-wheel comprised successively a hand-wheel geared and a Barker's mill.

The fundamental principle upon which the steering of the torpedo is based is this: If a revolving fly-wheel be acted upon by any force which tends to turn it about any axis not parallel to its own, there will be a resultant motion about an axis perpendicular to the plane of those two. The axis of the fly-wheel being horizontal, any extraneous force tending to deflect it laterally will cause the torpedo to roll, and this fact is availed of to oppose a contrary effort, so as to compel it to travel on the straight course in the horizontal plane.

Without going closely into the details of the mechanism, the rolling motion is utilized through the agency of a pendulum, which causes motion to be transmitted to two vertical rudders, which tend to deflect (and consequently roll) the torpedo back in the opposite way, thus neutralizing the original effort. The position of the pendulum relative to the transverse planes of the mechanism determines the position of a palette or rocking arm, which may be either parallel to or tilted one way or the other with regard to a circular cam-wheel surface, which latter is kept rotating by a worm on the propeller shaft. The arm tilted toward the wheel catches in the cam-rib in each revolution, the resultant action being to throw the tiller (and rudders) over for an instant; this being repeated at short intervals causes an efficient but not undesirably vigorous reaction. The lower the speed of the torpedo, the less rapid are these impulses. When at rest there is no natural initial stability, the centre of gravity coinciding practically with the centre of figure.

To control the submersion recourse is had to a horizontal rudder, which is operated automatically by mechanism whose action is controlled by a combined pendulum and hydro-pneumatic cylinder, the piston of which moves with the varying external pressures at different depths. By a tilting arm and cam-wheel the action of this pendulum (which swings fore and aft) is transmitted in impulses in much the same way as for lateral steering, the effect being to preserve horizontality of longitudinal axis; but the action is modified by the piston, which by its telescopic action in the cylinder changes the centre of gravity of the pendulum, causing it to turn in one direction or the other.

At the after end of the torpedo, surrounding the propellers, are tubes which, by reason of the mass and velocity of water flowing through them, serve to stiffen the path against irregular movements in the vertical plane.

The propulsion is now by twin screws, the shafts being geared direct to the axle of the drum. The initial speed can be varied by changing the pitch of the propellers, or by altering the relative sizes of the mitre-wheels on the shafts and fly-wheel axle. To revolve the fly-wheel its axle is grasped, through a clutch, by the driving shaft of a Barker's mill, which is disengaged when the requisite speed of revolution is acquired. The torpedo is then ready for launching.

As at present perfected the torpedo is 8 feet long, 13.3 inches in diameter. The shell is of spun copper. Total weight 325 pounds, including 70 pounds of explosive. Guaranteed speed 23 knots for 200 yards, with a total range of 800 yards. The fly wheel is of steel, weighs 110 pounds, and is spun up to 10,000 turns a minute, thirty seconds being required to attain that velocity. In larger models the proportion of charge to total weight will be about one-third.

The discharging gear used up to the present time consists of a frame or derrick extending from the ship's side, under which the torpedo is hung by clutches and studs on its shell. This frame is either pivoted on the rail or fitted to slide in and out on a stationary beam; in either case the torpedo can be conveniently slung from the deck, and on being rigged out is then operated by two lanyards. Steam being turned on the Barker's mill, and the drum spun up, one lanyard, acting on a trigger, disengages the clutch connecting the two; the other lanyard, acting also on a trigger arrangement, disengages the torpedo from the clutches, leaving it free to fall. To give it an impulse in the direction in which it is launched the torpedo is also grasped abreast the centre of gravity by a downward swinging clutch, pivoted outboard on the frame beyond; on being detached from the derrick, therefore, it does not drop vertically into the water, but is swung outboard in the arc of a circle, being detached automatically by a check-line and trigger on reaching the vertical below the pivot. This gives it an impulse without changing the angle of its longitudinal axis with the surface of the water.

The supporting frame is free to swing below an axis parallel to the fore and aft line of the torpedo, so the axle of the fly-wheel is also kept horizontal.

An improved apparatus, however, has been designed for service. This comprises a tubular shield, in which the torpedo will be placed within the ship or boat. At the inner end are two compressed-air cylinders whose piston-rods reach forward and press against studs on the middle body. The tube and support revolve about a centre to allow lateral training, the power for revolving the fly-wheel being conducted through this centre. Steam from the Barker's mill exhausts back into the condenser, thus stopping the humming sound to which great objection had been justly raised. The mill clutches the axle until the torpedo is launched. By one action of a lever the power is shut off and the torpedo ejected.

The mechanical success of this weapon seems assured. In the last few years it has been subjected to trial before naval boards in the United States and found to possess valuable qualities, chief among which may be mentioned its strong directive force and its comparatively small size. In recent experiments the diving apparatus also worked promptly and effectively. Besides the inherent directive force, the following elements of superiority are claimed for it over the Whitehead types: It is a much cheaper article; for the same size and weight it carries a much heavier charge; it does not possess the element of danger contained in the air flask, the rupture of which (by accident or hostile shot) has already been shown to be destructive to life and property; its track is not betrayed in daytime and clear weather, by air bubbles. Granting that the humming noise is stopped, the remaining objectionable feature is the fact of its not lying in a state of constant dormant readiness, but having to be spun up before it is ready for use. It is claimed that this apparent defect does not exist to the extent stated, as when the wheel is once started it takes but little power to keep it going, and it can be spun up from the time of the vessel's going into action until hauling out.

Mallory.—A means of propulsion and horizontal guidance, patented in 1880 by W. H. Mallory, of Connecticut, may be regarded as one of the links in the chain of thought that has been brought to bear on the subject of movable torpedoes. As proposed, the weapon is not provided with apparatus for regulating the submersion, and it may perhaps not be properly called a fish torpedo for that reason, but that quality could be easily applied to it without detriment to the characteristic features.

The intention is to solve the question of stiffening the path in a horizontal plane, by imparting to the shell a rotary motion. To this end it is proposed to be cigar-shaped, 12 or 15 feet long, and about 10 inches in diameter. The motive power is applied by propeller blades mounted on a ring revolving round the body near the middle. The power is that of a number of heavy coiled springs, placed in series fore and aft concentrically round the middle axis; these are connected by double drums, the outer end of one spring being connected to the inside of the drum, while its inner end is connected to the spindle of the next drum. In this way the propeller will be revolved as many times as all the springs are capable of being wound. A key holds it fast when not in use.

The reaction between the shell and the propeller causes the former to revolve in the opposite direction from the latter. To control this tendency and prevent the expenditure of too much power in that way, wings are attached near the stern with enough spiral curvature to allow the torpedo to rotate about one turn and a half in advancing its own length.

The charge is in the forward cone, and may be fired either by percussion or at will. In the latter case a wire, connected with the electric fuze, is led out through the tail to the shore. This wire is so coiled in its compartment that the twist naturally given it in uncoiling is compensated by the rotation of the torpedo itself.

For service the torpedo is placed in a submerged tube. By withdrawing the locking-key, the propeller is started and the torpedo passes freely out.

Hall.—Like other fish torpedoes, that designed by Lieutenant Hall, U. S. Navy, has the shape of a spindle of revolution, carrying the charge in the nose, with a percussion apparatus. But in all other respects it differs wholly from those described above.

The motive power is steam, which, together with a suitable quantity of water heated to about 550°, is stored in a flask or generator. As the pressure is reduced by the consumption of the steam, the heated water gradually vaporizes, furnishing a continual supply. The engine drives two-bladed twin screws whose disk areas overlap, they being so placed that when the blades of one are vertical those of the other are horizontal; a simple gearing compels the two shafts to make the same number of revolutions, thus preventing any possibility of the blades interfering. By this means a large disk area is obtained.

The other special features in this torpedo are in the apparatus for regulating the submersion, no assistance being derived from the hydrostatic pressure. When ready for use the torpedo has a buoyancy of 15 to 30 pounds. To cause it to maintain a practically horizontal path under water, a pair of diving-fins is fixed on the nose, inclined downward to an extent found sufficient to counteract the buoyancy, the depression of the nose being checked by a drag made fast to the tail, which by pulling back on it has a tendency to bring the stern down to a level with the bow. As the steam and water are used, the buoyancy increases, and the angle of the diving-fins has to be increased proportionately. This is done in the following manner: within the shell of the torpedo, on each side, is a fore-and-aft cylinder containing a piston, one side of which is pressed by a spiral spring, and the other by steam or water from the flask. A piston rod goes forward to abreast the diving-fin, with which it is connected by a shaft through the shell and a system of racks and pinions; with the fins in their normal position, the steam pressure and that of the springs counterbalance each other in the cylinders; but as the water is used (increasing the buoyancy) its pressure decreases, and the springs prevail over it, and, pushing the pistons and rods, alter the position of the fins. In order that the fins should work efficiently it is necessary that the speed of the torpedo should be regular, and to that end a governor is placed on a prolongation of the shaft. This governor, while simple in principle, is extremely sensitive, and, moreover, can be regulated to control the speed to within twenty revolutions. In fact, uniformity of speed is depended upon, in place of hydrostatic pressure, to regulate the submersion.

It is evident that any rolling of the torpedo would cause the diving-fins to act with a lateral component; to prevent this, lateral righting fins are provided just abaft the diving-fins and below the horizontal plane of the axis of the torpedo. They are hinged at their forward end, and normally lie close in against the hull, being pushed out, when needed, by the righting engines, as follows: A double bent U tube, in a vertical thwartship plane, contains mercury; each vertical arm contains a valve chest floating on the mercury column; connected with each valve chest is a horizontal thwartship cylinder fitted with a piston and rod, which latter, passing through the shell of the torpedo, takes against the righting fin. When the torpedo rolls to either side the mercury rises on that side, pushing the valve up and opening the port leading from the flask to the cylinder, and the piston rod and fin are forced outward; the surface of the fin, being exposed to the upward pressure of the water outside and beneath the torpedo, causes it to roll back to an upright position, on attaining which the mercury falls in that branch of the pipe and closes the valve, and the fin is pushed back in place by the water pressure.

The Hall torpedo is still in the experimental stage. In the few trials carried on so far, it has been found to possess good and regular speed, and the lateral steering apparatus worked satisfactorily.

Peck.—The application of steam power for propulsion is also the prominent feature in a torpedo recently devised by Mr. Peck, of the construction department of Messrs. Yarrow & Co., the torpedo-boat builders. The flask will be charged to a pressure of only 400 pounds per square inch, the water passing through a superheater on its way from the boat's or vessel's boiler. It is calculated that the charging operation will not occupy over half a minute; and, as the reservoir will be clothed with a non-conducting material three-fourths of an inch thick, it is thought that the necessary heat and pressure will be maintained for about an hour.

An innovation in the application of power in this weapon is the employment of a condensing engine. A small space, about three-eighths of an inch, between the reservoir and the shell, and also a portion of the space in the body of the torpedo not otherwise occupied, is utilized as a surface condenser, the outside water being the refrigerant. There are three advantages in this arrangement: Greater power is gained by exhausting into a vacuum; the reservoir is better protected from chills; the weight and buoyancy remain constant, as the hot water, after vaporizing and being used, is condensed again.

The model proposed is of the usual Woolwich pattern of fish torpedo outside, 14 feet long and 14 inches in diameter, and will carry 100 pounds of explosive. The hull will be of metal heavy enough to stand the external pressure of the water and atmosphere when a vacuum has been obtained within. The hot-water flask, at about the centre, is 4 feet long and 11½ inches in internal diameter, and will be charged with about 160 pounds of water. The engines are expected to develop 60 horse-power and drive the torpedo at an initial rate of 30 to 32 miles an hour, the total range, of about a mile, being less or greater according as the initial speed is greater or less. The usual fins and immersion apparatus are provided for regulating the depth and steadying the course.

Paulson.—Another form of automatic fish torpedo lately produced is the Paulson, which differs from others in being self-steering on a compass course. The motive power is liquid compressed carbonic acid, stored under a pressure of 1,500 pounds, which is released gradually, and, volatilizing, passes through the nozzle of an injector surrounded by water from the sea; the gas imparts its energy to the water, being itself condensed, and the water thus charged is forced through the combining cone of the injector, and drives turbines, the shafts of which transmit motion to screw propellers. These motors exhaust through the hollow shafts which project some distance astern. In the model of 1885 twin screws were used, but later designs have but one.

The steering is automatically effected by electricity, a secondary battery being provided, the negative pole of which is connected with two sets of electro-magnets, each of which is connected with one of two metal pins on a disk of insulating material; the positive pole is in permanent connection with a compass needle pivoting on the centre of the disk. The disk is turned so that with the torpedo pointing in the desired direction the point of the magnet needle will be between the two metal pins, which is tantamount to shaping a compass course. Should the torpedo deviate from that course one or the other metal pin would come in contact with the needle, and complete the circuit through the coils of one or the other electro-magnet. In the early forms, with twin screws, these magnets operated valves decreasing the admission of water to one motor and increasing it for the other; but in the latter model, with one screw, they operate the rudder.

The patent specifications (1884) provided that an additional balanced magnet should be so placed and arranged that on coming within the attraction of a mass of iron, such as a ship's hull, and being attracted to any given degree from its normal position, it would short-circuit and cut out the connection between the steering needle and the studs, and act upon the rudder or propeller without regard to the position of the steering needle, and turn the torpedo towards the point of attraction. In recent models this second magnet is omitted.

The submersion is regulated by the pressure of water acting on a flexible diaphragm against a spring set to the proper tension. By a system of rods and levers this apparatus actuates diving fins at the tail of the torpedo.

The material of the hull is a compressed water-proof paper. The external shape is cylindrical with pointed ends, the rear being much longer than the forward cone. Two sizes have been designed; the smaller one, 12 feet long and 12 inches in diameter, is for countermining; by the aid of clockwork it is to be steered straight for a specified distance and then run in curves; on coming within the attraction of a mine-case it is intended to run for it and explode on contact. The larger size, for operations against ships, is 25 feet long, and is expected to make a speed of 25 to 30 knots, with a total range of 1,000 to 1,500 yards.

Many attributes are claimed for the Paulson torpedo. It may be controlled by a wire for any desired part of its range, and then freed from it automatically. After running in any direction for any specified distance (within the limits of its range), the compass card can be made to turn exactly round so the course will be changed to the opposite direction; also at any time a safety-bolt can be pushed automatically to prevent explosion. A minor charge of 10 pounds of gun-cotton is carried on a short outrigger from the nose, fitted with special triggers which are sprung on striking a net, the idea being that this charge, in front of a torpedo going 25 knots, would cut any net but not explode the main torpedo charge, which would then be free to act on the ship's bottom.

Remarks.—The various models of fish torpedoes thus briefly described, unite most of the essentially typical features that have been brought out in connection with the evolution of that weapon. An analysis of the various characteristics of each will lead to the conception of a composite pattern uniting the elements of superiority of two or more of those perfected designs.

In the matter of discharging them in action, the science can perhaps not be said to have entered upon a thoroughly practicable plane until that is satisfactorily performed under water. The possibility of being disabled, or exploded by the enemy's fire, the variability of the height above the sea from which it is dropped or shot when the ship is rolling or pitching, and the possibility of its striking the water tail first from the same cause, are powerful arguments against above-water discharge. The difficulties of ejection below the surface are mechanical. Discharge in line with the keel, while attended with some difficulty, is in general favor; but when fired on the broadside or bow the pressure of passing water tends to drive the nose of the torpedo aft before the tail is clear. This has been obviated to a certain extent by the use of projecting shields, just forward of the tubes, but target practice off the beam when under way has not been found thoroughly satisfactory. Furthermore, above-water tubes are easily made capable of train through 90 or more degrees of horizontal arc, which is difficult of accomplishment under water, and has not as yet been effected in service.

The problem may possibly be made easier of solution by the advent of a weapon possessing an inherent directive force that shall enable it to successfully overcome the deflecting forces incidental upon ejection into a medium having a rapid motion relative to its initial point.

CONTROLLABLE TORPEDOES.

In 1870 a type of submarine weapon was produced totally distinct in principle and employment from any of its predecessors. As indicated by the name given in the heading above, it is kept under the control of the operator. In the gradual development of this torpedo different systems have been evolved, which may be divided into two general classes, viz, those that contain their own motive power, and those in which the power is communicated from the operating station.

Callender.—Although the year 1870 was the one in which these weapons were first known in a practical and useful form, one must go back to 1862 for the first notable attempt in that direction. A dirigible rocket torpedo, patented in that year by M. L. Callender, of New York, is of interest as containing features that have recently reappeared in a model that has attracted some attention. The shell was of metal, cylindrical, with tapered ends, and intended to float at or below the surface. The composition was in a chamber in the forward end, the gases exhausting through a nozzle in a projection immediately beneath it. About the middle of the shell was a cylindrical chamber slanting downward and forward, and opening through the bottom, containing a projectile, which was connected to the bow of the torpedo by a chain. A small charge of powder, ignited on impact, fired the projectile downward and forward, and the chain caused it to swing upward against the ship's bottom, exploding by percussion.

At the after end was a false keel and a rudder, the latter carrying a yoke operated by light lines leading to the shore or ship. By checking one or the other line the yoke and rudder would be pulled over and the course changed.

Lay.—The first controllable torpedo that reached the phase of being an actual service weapon was, like the Callender, of the automobile class, but the power was that of carbonic acid gas, liquefied under pressure, and applied through a screw propeller. The inventor was Mr. John L. Lay, who, in conjunction with Chief Engineer Wood, had, during the American civil war, devised the Wood-Lay spar torpedo. This new production moved at the surface, and, on being started by hand, ran until the power was exhausted. It was steered by means of a gas engine working a rudder, the valves being controlled by electromagnets. A battery for exciting these was carried in the torpedo, and its circuit was completed through the proper magnet by means of a current sent over a single-conductor cable paid out from an orifice in the bottom of the shell as it advanced. The hull was spindle-shaped, 25 feet long and 30 inches in diameter.

The main defect in this first model was the inability to stop and start at will, and the next one, completed in 1872, was fitted with electromagnets to control the engine valves, besides those to work the helm, the cable containing two wires. This torpedo was also larger, being 29 feet long and 36 inches in diameter. It weighed 4 tons, had a buoyancy of 200 to 300 pounds, and carried 500 pounds of explosive, which was fired by four sulphuric acid fuses. The propeller was four-bladed, and driven by oscillating engines. To prevent alteration in trim due to the consumption of gas, of which 550 pounds was stored, the weight of the latter was compensated by the introduction of water, pound for pound, through a valve of peculiar construction. Two sight-rods, carrying flags by day and lights by night, were attached to the upper part to assist the operator in steering.

This torpedo was bought by the U. S. Navy Department for trial at Newport, and much difficulty was found in making it come up to the terms of the contract. In the first place the electrical apparatus gave trouble chiefly from the two conductors making contact; this was obviated by using a single wire and an improved relay and key-board designed by Mr. M. G. Farmer, with which the local battery could be connected at will with any one of the four magnets. Briefly: The main battery (on shore) consisted of six Bunsen cells connected in series, the zinc pole of the battery and the carbon poles of the second and sixth cells being connected with the key-board, so that practically currents from two batteries (one of two cells and one of six) could be used; as either positive or negative currents could also be sent out to the relay, four currents were available which would respectively stop, start, port, or starboard the torpedo.

The low temperature caused by the vaporization of the acid was also found to militate seriously against the effective use of that motive power, as the pressure falls with the temperature and the gas becomes very sluggish. Difficulty was experienced, moreover, in obtaining flasks that would stand the required pressure of 1,800 pounds.

In 1873 Mr. Lay produced a third model with a dropping magazine. In this one the attempt was also made to perform the functions of start, stop, ahead, back, port, starboard, dive, rise, and fire, requiring in all nine circuits. To do this a double polarized relay was used and a "step-by-step" apparatus with a single wire; for diving, a pair of fins was acted upon by a small electrically controlled engine, water being admitted forward at the same time; to rise, the fins were reversed and the water ejected by gas.

All these evolutions were successfully performed at the first trials, but afterwards it could only be made to start, stop, starboard, and port. The following arrangement was extemporized for firing: The magazine in dropping pulled out a cork, allowing water to enter a chamber where an earth plate was kept, completing a circuit through the fuze.

The models constructed in succeeding years contain many varying features. The single conductor was replaced for a while by a multiple cable, which, however, was discarded again later. Three-cylinder Brotherhood engines were introduced, the gas being admitted constantly to the crank pit and two of the cylinders, the third being open to the exhaust; these did not permanently displace the oscillating and other engines. An exhaust was provided through the hollow shaft. Circulating water was admitted round the flask to keep up the temperature longer. To the same end the experiment was tried of admitting steam into the flask compartment, just before the run, to heat it. The pressure rose quickly from 425 to 1,025 pounds; but this artificial heat was quickly used up. On the trial a mile was run at the rate of 7.17 miles an hour. Thin sheet steel finally replaced iron for the hull, and was in turn superseded by copper.

In 1877 two important and permanent changes were made—one was in the adoption of a polarized relay for use without a local battery (in the torpedo); the other was in leading the cable out astern through a hollow propeller shaft.

To overcome the great instability an oblique cone shape was tried for the ends, the lower side being in line with the bottom of the torpedo. This was evidently just the wrong thing to do, as it increased the buoyancy of the bottom part. In a design patented later by members of the United States Torpedo Company, the forward cone was kept straight and the rear one oblique, the upper side being in line with the cylindrical body. This form gave great stability and permitted a lowering of the propeller into more solid water, its shaft being actuated by three-to-one gearing on the engine shaft. Reynolds's patent in 1881 also provided for two propellers of opposite pitches, side by side, rotating in opposite directions and intermeshing; to better provide for this arrangement, the stern was a horizontal-faced and horizontal-ended wedge. ' In this design horizontal rudders were fitted, worked by an electrically controlled gas engine, to direct the course up or down.

Exhaustive trials in the United States and Europe proved that the Lay torpedo was completely under control, night or day, in smooth or rough water, and in strong currents, and was favorably reported upon by various naval boards. In 1880 the speed had risen to 11¼ knots for a number furnished the Russian Government; but in those the plan of exhausting through the propeller shaft had to be given up, as it was found to clog the cable by freezing. These were also fitted with dropping magazines, and the sight-rods could be raised or lowered at will. A mile and a half of four-conductor cable was provided, a 50-cell battery being used.

In the later history of this torpedo many new names appear, mostly of men employed by Mr. Lay, but whose connection with him became severed in course of time. The originator of the type, having transferred his field of work to Europe, continued his experiments independently of his former associates, and has just produced a new weapon in England.

Improved Lay.—The principal point of difference between this model and its forebears is in having the propellers forward, in a recess 3 feet from the bow; the object being to render the torpedo more amenable to control. The recess nearly divides the explosive chamber from the rest of the hull, being entirely open except at the top; the after side is beveled away to give passage for the wash of the propellers in the upper part of their revolution. The screws are of peculiar design and application; the two are on a common shaft, which runs through the recess close to the bottom; the upper part of the revolution is within the recess, and the lower part entirely in the solid water underneath. In each propeller the two blades, instead of being on opposite sides of the shaft, are close together, the leading edge of one coming just behind the following edge of the other. One propeller is rigidly attached to the shaft, the other is loose upon it, but made to revolve with the former by an interlocking boss. Normally the two sets of blades are folded together, covering a sector of about 70°, and stand upright within the recess, protected from all injury. On-starting the engine the one attached to the shaft begins to turn, and when it has made half a revolution its boss engages that of the other, after which the two revolve together, their blades being in opposite sectors of the disk of revolution.

The torpedo is cylindrical, with a short, conical head and vertical wedge stern, 23 feet long, 18 inches in diameter, and said to weigh about 1¼ tons; it moves at the surface and carries 200 pounds of explosive in the forward cone. A vertical rudder is hung aft, actuated by an electrically controlled gas engine, and a pipe projects astern, through which the engines exhaust and the cable is paid out. There are arrangements by which it can be submerged by admitting water, which can afterwards be expelled by the gas pressure. The power is applied through a spherical engine, and a speed of 16 knots is claimed, with a range of 2 miles; but at a public trial at Brightlingsea, England, in March, 1887, it heeled over so as to throw the propellers partly out of water, which prevented a successful performance. The causes of this were apparently temporary and may probably be remedied.

Lay-Haight.—In 1881 a new model, known as the Lay-Haight, was built by Mr. Haight, formerly in the employ of Mr. Lay. It had a vertical wedge bow, and an oblique cone stern, straight on top; length 23 feet 10 inches; total weight when ready for service 2,035 pounds, including 150 pounds of explosive. The main points in its design were these: Eighty pounds of pig lead were put on the starboard side, which gave it a list when not in motion, but which when under way counteracted the heel to port, due to the action of the screw; the engine chamber, containing the 3-cylinder Brotherhood engine and the gas expanding tubes, was open to the sea to draw heat from it. A great change from preceding practice was in drawing the acid from the flask in a liquid state and expanding it outside in copper tubes exposed to the sea-water. By drawing it off in the gaseous state, all the expansion and consequent fall of temperature had occurred in the flask, causing great decrease of pressure. In consequence of this, apparently, a speed of 12 knots was attained. A single wire was used, currents being taken from three different numbers of cells.

The question of preventing the fall of temperature had been a subject of much study at different times and places. Professor Hill at Newport suggested quicklime and water early in the history of the dirigible torpedo, and later proposed sulphuric acid and lime to produce the required heat. This was tried and it proved successful in an "improved Lay-Haight" or "combination" torpedo built by the American Torpedo Company in 1883, a speed of 15 knots being realized.

Completed up to this point the Lay torpedo may be said to have been laboring under the following disadvantages: Being a surface weapon, it was vulnerable to machine-gun fire; it was liable to pitch and throw both propeller and rudder out of water; the propeller being so near the surface and unprotected was easily fouled, as also the cable; unless fitted with a dropping magazine the explosion took place at the water line. In the last model the action of the chemicals in the gas-expander was brought about by turning a crank, which, by a cog-wheel and worm, revolved a trough, ripping off its cover and precipitating the lime it contained into the acid; this caused an undesirable delay in preparing for a run.

Patrick.—All these objectionable features were done away with in the weapon commonly known as the Patrick, the latest perfected pattern of the Lay type, which was tried in 1886 in presence of inspecting boards of various countries. It is kept at a submersion of 1 metre by being made heavier than its displacement and sustained by a float which is practically indestructible by mechanical gun fire during the short time that it would be exposed. As a further result of this arrangement the propeller and rudder work in solid water, and the former cannot easily be fouled nor the cable grappled; the explosion also takes place under water. In the application of the motive power as well as in many other details it differs from other previous models.

The float is fusiform, 41 feet long with a maximum diameter of 12 inches; it is made of sheet copper one-eighth of an inch thick, filled with lampblack, and carries two guide-rods with flags.

The torpedo, made of the same metal as the float and rigidly connected with it, is also fusiform, 36 feet long and 22 inches in diameter. The nose projects a short distance forward of the float, the latter extending well astern to correct the tendency to bury aft. The propeller is two-bladed, on a hollow shaft through which the cable is paid out. The acid, drawn in liquid form from the bottom of the flask, is taken through copper piping in the bottoms of the heaters. These heaters are copper cylinders containing dilute sulphuric acid, each having a cylindrical trough in the top holding the lime; the latter is divided longitudinally into two parts kept closed by a series of hooks on a common rod; this rod is connected with a piston in a cylinder outside the heater. A pipe leads from the steering-engine to this cylinder, and by putting the helm to port (before starting the main engines) gas is admitted to it, drawing back the rod, freeing the two parts of the trough, which are then forced apart by springs, and dumping the lime into the sulphuric acid.

The propelling engines are of the "diamond" type, six double-acting cylinders being grouped longitudinally about a central shaft, friction rollers attached to their cross-heads working in a zigzag cam groove on the surface of a drum attached rigidly to the shaft. They exhaust through the hollow shaft, and have made as high as 1,100 revolutions. The rudder is balanced and placed forward of the propeller, on top of the shell. With the helm at "steady", the rudder is slightly to starboard to counteract the throw of the propeller. A charge of 200 pounds of dynamite is carried, which is fired electrically at will or by contact. To perform the functions of start, stop, starboard, port, and fire, a two-wire cable is used in connection with 80 Bunsen's cells arranged in series. The cable is about 7,000 feet long, with a diameter of nine 64ths of an inch. The whole outfit weighs 4,700 pounds; the torpedo proper weighing 3,800 on a displacement of 3,400 pounds. During various trials in the summer of 1886 at College Point, Long Island, the speed was found to be 19 to 19½ miles for a mile per hour; on one occasion the first half mile was made at the rate of 22.15 miles. It also obeyed the helm promptly and was easily guided.

The speed and perfect control of this torpedo, the invulnerability of the shell and the protection afforded the propeller and cable, combine to make it a weapon of rare excellence for harbor defense. A discussion of its merits as a naval weapon would open tactical questions not always easily settled.

The Patrick is the only controllable torpedo of the automobile class that has achieved final practical success, but in almost every one of the many other patterns designed there has been a certain amount of originality bearing fruit of greater or less value.

Coda-Canati.—The Coda-Canati torpedo, developed under governmental auspices by the Italian officer of that name, is a weapon of the same general nature as the Lay, being propelled by carbonic acid gas and controlled by electricity. It is intended, however, to have a much larger range, and to carry a much heavier charge, and is more bulky in consequence. In the application of both motive and controlling power there has been much independent mechanical equipment which is naturally kept secret.

Von Scheliha.—Contemporaneous with the early models of the Lay was that built in 1871 in Russia by Colonel Von Scheliha, late of the Confederate army during the American civil war, which was not finally adopted, but which contained several features found later in its more successful rivals. The motive power was compressed air, at about 300 pounds pressure, applied through an oscillating, geared engine driving a four bladed screw. The steering was effected by electric circuits exciting two magnets which acted directly on the rudder yoke. The cable, which contained three wires, one for each magnet and one for firing the charge, was a mile long, wound on a reel in the engine compartment and paid out through the hollow shaft, being apparently the first thus fitted. The shell was of the usual cigar shape, made of sheet iron 20 feet long and 30 inches in diameter; the total weight, about 4,000 pounds, was somewhat in excess of the displacement, and positive buoyancy was afforded by a float which also served as a mark for the operator in steering it. The weight remained approximately constant, water entering through the hollow shaft and taking the place of the cable.

Smith.—In the Smith torpedo, built in 1872, there were many mechanical details that contributed to its success and value as a weapon, and it would possibly be in use to-day but that the device for controlling the engine valves was decided in law to be the property of Mr. Lay. At the time of its trials at Willets Point, it was thought, by General Abbot, to be superior to the Lay.

It was of the automobile class, the power used being liquid ammonia or any other gas applied through an oscillating engine to a screw propeller. The case was of iron, of a very short and thick cigar shape, with a keel and rudder and a float to sustain it at a desired depth; the latter was connected with it by a trigger-rod extending ahead, detachable on impact. The explosive charge occupied the forward one of three nearly equal compartments. The middle section held the gas flask and also the cable, which paid out through the bottom; this compartment was open to the sea to furnish heat during the expansion of the gas. At the after end were the engine and magnets for propelling and steering. For the latter function a horizontal thwartship cylinder was placed just forward of the rudder-head and connected with it by a rack and toothed sector; a fixed hollow rod perforated by small holes traversed the cylinder from end to end, carrying a piston rigidly attached; normally, with the rudder amidships, this piston was in the middle of the cylinder. On gas being admitted, through electrically controlled valves, to one end or the other of the piston rod, and through the perforations to the cylinder, the latter would be moved to starboard or port, turning the rudder by the gearing.

On striking the enemy the torpedo would be detached from the float and descend while continuing on its course, the explosion being effected by a friction primer attached to a long lanyard, the other end of which was made fast to the float.

Foster.—The Foster torpedo, patented in 1872, presented the novel feature of being propelled, as well as controlled, by electricity. The motive current was produced by a local battery, and that for steering was sent out through a cable. The former operated an electro-magnetic engine; the latter excited a horizontal magnet on top of a revolving drum, making it turn one way or the other, according as the current was direct or reverse, toward the arm of a larger magnet permanently excited by another local battery; on the drum thus caused to revolve was a flexible wire actuating the rudder yoke.

This weapon was intended for use at or below the surface; in the latter case it was to be made heavier than its displacement and suspended from floats. It was not a success, neither the motive nor the steering power being adequate.

Nordenfelt.—A more recent automobile electric torpedo is that patented in 1883 by Nordenfelt. The motive power was derived from local storage batteries, the control being effected as usual by cable from shore. The shell was cigar-shaped in horizontal section, rectangular in vertical sections, and made of sheet iron; a heavy wood or cork fin, broad at the base, ran the whole length of the top. The weights were so adjusted that without the fin the case would float and with it it would show a small portion of the fin above water. Two sight-rods stood upon this fin; they could be raised or lowered at will, and carried small incandescent lights which were thrown out of circuit when the rods were lowered. The cable held four wires—one for steering (by positive or negative current), one for opening or closing the motive circuit, a third for operating the sight-rods, and the fourth for firing the charge. One large battery furnished the motive power, and an auxiliary was provided for all other internal work.

A torpedo was built after this design in England in 1885. The motor was a Siemens dynamo operated by a current from 125 accumulators, calculated to give 20 horse-power. To carry this weight the shell was 35 feet long and 35 inches in diameter. A very fair speed was developed, but the performance in other respects was not wholly satisfactory. The effort of the propeller not being exerted in line with the centre of resistance, oscillations resulted in a vertical plane with a tendency to make it dive.

Berdan.—As movable torpedoes attained to a greater and greater pitch of perfection systems of defense against them were inaugurated, culminating in heavy steel nets hung at distances of 20 to 30 feet from the ship's side. To circumvent this is the leading idea in a mode of attack recently proposed by General Berdan. This scheme calls for two torpedoes, the power of one being slightly greater than that of the other, which is towed behind it by a line 30 to 40 feet long. The leading one is steered, the other following in its wake. The controlling apparatus, which recalls that patented by Callender in 1862, consists of two reels at the operating station, holding each a mile of fine plaited linen cord, the end of which is hooked to the rudder yoke; dynamometers and brakes are provided, by which the strain on one or the other end of the yoke may be increased. When the leader strikes the net the tow-line becoming slack lets fall a horizontal rudder under the second torpedo, causing it to dive until the tow-line becomes taut again astern, when it takes an upward circular course and strikes the enemy's bottom. For attacking a vessel not protected by a net the tow-line would be considerably shortened so as just to cause the second torpedo to strike under the bilge. The system affords another application; the first may be made explosive so as to destroy the net on striking it, and the second, not made to dive in this case, would follow through the breach thus effected.

To carry out this scheme General Berdan proposes a vessel cigar-shaped in horizontal and rectangular in vertical section, 31 feet long, 21 inches wide, and 31 inches deep, and weighing about 2,800 pounds; it is to run just below the surface, a disk on a rod showing above to assist in guiding it. The power is in the combustion of rocket composition, which is packed in three rows of four 100-pound tubes, and contains a certain amount of clay to limit and regulate the rate of burning. The gases generated rush through a nozzle and actuate a turbine on the propeller-shaft, the computed range and speed being 1 mile at the rate of 24 per hour. The explosive charge will be 220 pounds of gun-cotton or dynamite, fired by percussion.

Strictly speaking this torpedo is a dirigible rather than a controllable weapon, the operator being only able to guide it and not stop and start it at will.

Nealy.—The last production in the way of automobile dirigible torpedoes is the Nealy, just patented in the United States. The pith of the design is in encircling the cigar-shaped body with continuous spiral blades, and in rotating the body so that those blades shall produce the same effort as an ordinary propeller. A motor is provided geared to a central longitudinal shaft, which projects astern and carries a number of straight radial blades parallel to the axis and to the line of travel, so that they resist rotation and produce a reaction which causes the rotation of the shell of the torpedo. The latter is suspended by rods grasping the ends of the central axis, from a float which is normally just awash, but has a small hood, which, by a clock-work arrangement, is at regular intervals collapsed and expanded and may serve as a mark to guide it by. The supporting rods enter recesses in the bottom of the float, and their eyes engage hooks on a longitudinally sliding shaft, which projects in front of the float, and on striking a vessel, is pushed back, detaching the rods; the torpedo then sinks while still moving forward and strikes the enemy at a lower point.

The patentee says the power will be preferably that of a spring, but does not limit himself to it. The float has a rudder to be controlled "in any well known way," presumably by electricity.

This weapon having been just patented, may be said to simply illustrate a principle, and will probably be proven valueless or the reverse by trial in practice.

Ericsson.—Of torpedoes moved by a propelling force generated at the operating station, the first brought forward was the Ericsson, a wholly submerged vessel fitted with diving and steering rudders. The special feature of this weapon was the conveyance of the motive compressed air to the engine through a tubular cable from the shore. Alterations in the air pressure were designed to effect the lateral steering, and the submersion was regulated by the hydrostatic pressure through the agency of fins.

The first model was built in 1873, although plans had been prepared some years before. It was 15 feet long, 2½ feet deep, 20 inches wide, weighed 2,000 pounds, and carried 150 pounds explosive. The motive machinery consisted of two bronze oscillating cylinders, which exhausted into their own compartment, driving the water out and giving a buoyancy, when under way, of about 50 pounds. Two propellers were used, revolving on the same axis in opposite directions, the forward one being on a hollow shaft round the solid shaft of the other, and driving it by means of an idler. The air-hose was 800 feet long, and buoyant; it was paid out from a reel on shore, and connected with a pipe projecting abaft the propellers. The speed attained was 3 knots.

On each side of the shell was a diving fin set normally at an angle of 30° with the horizon, which during forward motion would overcome the buoyancy and cause the torpedo to descend. The common axis of these fins was connected by an arm with an iron weight, moving vertically and piston-tight in a cylinder, and acted upon directly by the water underneath. The weight was such that on attaining the desired depth it was pushed in and up by the water, rotated the axis, and reduced the angle of the fins. Various mechanical modifications were found necessary, but that principle was adhered to and worked satisfactorily.

The apparatus for lateral guidance proved less successful. The compressed air constantly admitted to a chamber, acted upon an equilibrium valve, the stem of which had an arm carrying a weight. A normal air pressure counterbalanced this weight, and the steering piston remained unacted upon, springs attached to the yoke keeping the rudder amidships. If the air pressure were decreased, the weight overcoming it was to move the valve, admitting air to one end of the steering cylinder, causing the piston to travel and move the rudder to starboard. By increasing the pressure the weight would be overcome, and air admitted to the other end of the cylinder, with the consequent opposite effect. At first the rudder was placed on top forward; then it was changed to underneath on the same spindle, and finally had to be moved aft.

No firing apparatus was provided, but the design was to release a percussion hammer by a still greater pressure than that needed to turn to port.

In a subsequent model, completed in 1877, some improvements were attempted, but the production in general was less successful than its predecessor. The diving fins were attached to the shell at a fixed angle determined by experiment; the hydrostatic apparatus acted on a pair of small movable fins, which, at the proper depth, became inclined in such way as to counteract the effect of the others. The hose was coiled on a reel in the torpedo itself, and did not have to be dragged through the water. Moving at the surface this model attained a speed of four knots for 500 feet.

It was an unpractical weapon, having a very short range, and low speed, being operated by complex and noisy machinery at the station, and requiring great care and skill in its manipulation. It therefore did not survive. Its early plans, however, bore the fruit of furnishing to fish torpedoes means of neutralizing the throw of a single propeller by fitting two, on a common axis, revolving in opposite ways.

Scott.—The general principle involved in Ericsson's torpedo was revived in the Scott, patented in 1885 and 1886, the motive power being compressed air supplied through a hose from the operating station. It was fitted with twin screws and the steering effected by stopping the port or starboard engine. In one design the cable contained one flexible tube for the air, and one electric wire leading to magnets controlling the engine valves; by sending out positive or negative currents one or the other magnet would be excited and one or the other engine stopped. Another design provided for two tubes in the cable, one for each engine; by stopping the supply of air to either one the course would be changed. The cable was to be contained in the torpedo, paying out as it advanced.

The submersion was regulated by an equilibrium valve acted upon by the external hydrostatic pressure, which in one position admitted water, and in another admitted air to a pump which would eject the water, thus controlling the buoyancy.

For firing, the plan was to force the explosive chamber out at will by the air pressure, to be exploded on contact or by the tautening of a wire made fast within.

Sims-Edison.—In considering the problem of the transmission of power, the electric current has long occupied attention, and, as seen in the preceding pages, has been in use for controlling and directing torpedoes about seventeen years. For propelling them, so much more power is required that it was not studied with that function in view until later. Now, however, one of the most prominent weapons of the day is operated wholly through its medium. This is the Sims-Edison.

The first application of electricity for this purpose was in 1877, when Mr. Sims, after some preliminary experimenting with a small pulling boat, completed a cigar-shaped torpedo propelled and controlled by this essentially modern agent. It was not successful in point of speed, but a larger pattern built in the following year attained a rate of 6 to 7 miles, carrying 4,000 feet of cable. The perfection of the torpedo then became principally a question of the most efficient generation and application of power (by the dynamo on shore and the motor on board); associated with this was also the protection against machine-gun fire. In the model contracted for in 1880 by General Abbott, U. S. Army, for the Engineer School of Application, it was stipulated that it should be submerged and given positive buoyancy by means of a float; the guaranteed speed was 9 miles, but this was exceeded, 9.8 to 11½ being realized.

As now produced by the Sims-Edison Company, the torpedo has a copper hull, cylindrical with conical ends. Its range is limited by the amount of wire carried, and two sizes are in contemplation, one 28 feet long and 18 inches in diameter, to carry 1 mile of cable, and the other of the same length and 21 inches in diameter for 2 miles. The float, which is 20 feet long, is also of copper, filled with cotton, rendered impervious to water, so that if struck repeatedly by small projectiles it would still sustain its burden; in cross-section it is broad at the top and narrow at the bottom so that the buoyancy increases very rapidly with immersion. The torpedo is rigidly connected with the float by steel rods, the forward one of which, slanting to the rear and upwards from the nose of the former to that of the latter, will make it cut through or dive under floating obstructions. Two sight-rods on the float assist in steering, carrying balls in the day and hooded lights at night; they are kept erect by springs which permit their being bent back when diving under a boom.

A 20-light Weston dynamo machine is now used, supplying 30 amperes, with 600 volts E. M. F. The cable, which enters from underneath near the middle, is composed of two cores; one conveying the power has 20 No. 20 copper wires, and the other 7 No. 23 wires for the control. The compartment in which it is coiled is open to the sea, and as the cable pays out it is replaced by water; but as it is heavier than water the weight decreases slightly toward the end of the run. A balanced rudder is placed on top of the after cone just forward of the propeller-guard; the spindle carries a yoke from which iron rods extend forward, terminating in the armatures of two large electro-magnets. The steering circuit, by means of a relay, turns the motive current from its normal path to earth, and switches a part of it through one or the other magnet, attracting one or the other armature and pulling the rudder over 25°. When the steering circuit is broken the magnets are cut out, the motor current passing to earth without traversing their coils; the rudder then comes amidships from the action of the passing water.

The 1-mile torpedo weighs 3,700 pounds (without the float), including a 200-pound charge of explosive, which is submerged about $3\frac{3}{4}$ feet, and which can be exploded at will or on contact. The speed is about $10\frac{1}{2}$ miles. The 2-mile torpedo carries a 400-pound charge, submerged 5 feet, and makes 10.2 knots.

It is to be noticed in this weapon that the motive power is inexhaustible, though the range is limited by the length of the cable; also that it does not contain the additional element of danger of a highly expansible gas. On the other hand, its speed may at present be said to be unsatisfactory, as ordinary steam-launches, of modern build, could intercept or overtake it. In the present mechanical status of electrical science, while any amount of electricity may be generated, the size of the insulated cable limits the amount that can be transmitted, and the economical efficiency of the motor limits the return of work for a certain current; but it is out of the question to make predictions concerning the future of this source of power, and it seems possible that the speed of this torpedo may be increased. The company now proposes to use a single-core cable through which the motive power will be transmitted, momentary alterations in the strength of the current constituting the means for changing the course; by this arrangement increased sectional area of wire will be secured with consequent possible increase of current. Modifications will also be introduced in the form of the float, which at present offers unnecessarily great resistance.

Brennan.—The most recent invention of prominence in movable torpedoes is the Brennan, which belongs to the same category as the Ericsson and Sims-Edison, in that the motive power is not contained in the torpedo itself. It is not given positive buoyancy by means of a float, but may be regulated to proceed at any depth. The mechanism for this function is not claimed as new, the power to produce it being the hydrostatic pressure acting against a spring, the resultant effort being transmitted to diving-fins near the tail. A steel blade projects above water for the guidance.

The propelling power is produced and applied in a perfectly novel way. Within the shell (the vertical sections of which are rectangular, and the horizontal cigar-shaped) are two reels on separate shafts, containing each a certain length of fine steel wire, the ends of which are led out through the top of the shell, through fair-leaders on the tail, and thence to winding engines at the operating station. By pulling back on these wires the reels are made to revolve, and by mitre wheels on their axles cause the propeller shaft to turn. Each reel contains a length of wire equal to four times the distance to be run. At first charcoal iron wire was used, but since then fine steel wire, such as is used in deep-sea sounding, has been adopted.

The lateral control is effected by revolving the drums at different speeds. In the first models, with one propeller, patented in 1877, it was done in this way: one of the drums was geared to a solid propeller shaft, and the other to a hollow shaft on the solid one; at a convenient point on the solid shaft a thread was cut for a certain distance; abreast of this two longitudinal slots were cut through the walls of the hollow shaft, so that a sleeve or nut on the latter could by a projecting screw-thread engage in the thread on the former. When the two shafts were revolving at the same rate of speed the sleeve remained in one place; if one revolved faster than the other the sleeve was made to travel one way or the other by the action of the screw-thread. A score round the outer surface of the traveling sleeve took the studs of a clutch by which a lever was moved which communicated motion to the rudder.

Facilities have been given the inventor for perfecting this torpedo at Woolwich, and it has recently been acquired by the British war office, having apparently reached a high state of efficiency. In the original the solid and hollow shafts drove the same screw, the latter gearing on the former abaft the steering clutch; afterwards, however, the principle of two propellers was adopted, necessitating a change in the steering mechanism.

Recent trials have been very successful, a speed of nearly 20 miles being reported, with a range of about a mile.

In the foregoing pages all prominent submarine weapons have been described more or less briefly, and without dipping into national or private secrets. Note has also been made of other designs which, while not crowned with success, may have contributed a mite toward the general sum of knowledge, or may have simply indicated a special comprehension of some particular principle. It would be impossible as well as undesirable to describe all the productions of the host of eminent and skillful designers whose elaborate plans and models ornament the files of different patent offices. Many ingenious contrivances may be found there stored, which, for lack of practical value or of the needed "sinews of war," or for other reasons, have not created the stir in naval circles possibly anticipated by their inventors.

In submarine, perhaps, more than in any other branch of destructive science, is it necessary in time of peace to prepare for war. Little or no advance in the art has ever been made during any international or internecine conflict; nor has there been frequent opportunity to try in action any of the formidable weapons recently produced. Before acceptance they are subjected to tests supposed to be as crucial as those of actual war; but in practice, in different evolutionary squadrons, their offensive efficiency has been found much less perfect than desired. It is nevertheless true that their existence has served to greatly modify the policies and tactics adopted by admiralties and naval commanders, and it seems probable that in a perfected form they will constitute an important factor in the decision of future naval battles, as in the successful defense of ports.

II.

THE ELECTRIC LIGHTING OF UNITED STATES SHIPS OF WAR.

By Ensign S. Dana Greene, U. S. N.

The lighting of ships of war, in fact of vessels of all kinds, by electricity, is a development of the last four or five years. It is a subject that has grown in importance with the requirements of modern times, until, at present, an efficient electric lighting plant is regarded as one of the necessities of a modern vessel of war. The advantages of the electric light, and especially the incandescent lamp, over the old oil lamp and candle are many and great, and it is safe to say that any one who has had any experience with the former will testify as to its superiority over the latter for ship's use. The advantages of the electric light, briefly stated, are—

(1) Less liability of fire, since there are no uncovered lights about the ship. This applies to a well-installed plant, where the insulation of the wire is carefully looked after.

(2) The great reduction in the amount of heat generated by the lights, which in warm climates is a source of considerable discomfort to officers and men.

(3) The ship can be thoroughly lighted from spar deck to hold, and, with an independent switch for each lamp, any one can be turned on or off at pleasure.

(4) A ship well lighted below adds much to the health, comfort, and cheerfulness of all on board; and the necessary accompaniments of oil lamps, disagreeable odors, smoke, and frequent trimming, are done away with.

(5) With electric lamps there is no vitiation of the air by the consumption of oxygen.

The first cost of the electric lighting plant is, of course, greater than for the oil lamps, but after this, with intelligent handling, an electric plant should cost no more to operate than the oil lamps. In fact, experiments on board the English vessel Colossus prove that the electric lights are much cheaper than oil lamps to operate.

The increase in first cost is a necessary price of increase in efficiency; and it should be remembered that everything about a modern man-of-war, her hull, engines, armament, and equipment, while they are much superior to what they were twenty years ago, are also much more costly.

The Bureau of Navigation of the Navy Department was not slow to appreciate the advantages which the electric light promised for use on board ship, and early in the year 1883 specifications were prepared and arrangements made for lighting the U. S. S. Trenton, then fitting out at New York for her second cruise, by the incandescent electric lamp. The fact that she was the first man-of-war in the world to be so lighted, and that the experiment was tried with a view to ascertaining the practical efficiency of the electric light on shipboard, naturally excited at the time considerable interest both in and out of the Navy.* Seven electric lighting companies of the United States were asked to bid for the work; and it is worthy of note that out of the seven only one was prepared at *that time* to meet the requirements called for by the Bureau's circular. To the Edison Electric Lighting Company was awarded the contract of installing the first electric lighting plant to be used on one of our vessels, at a cost of $5,500. The contract called for one dynamo and engine complete to supply light to the following lamps: 104 16-candle power lamps; 130 10-candle power lamps; and 4 32-candle power lamps; a total of 238 lamps and 3,092 candle power; 238 key sockets for lamps, 6 extra brushes, 1 automatic regulator, 1 dynamo foundation. All of the necessary conductors, switches, safety devices and appliances were to be of the most approved patterns then used by the Edison company, and the fixtures for the lights were to be supplied by the Department. Such a contract at the present time would seem very general and incomplete, but it must be remembered that there was no previous experience to be guided by; and lacking such experience the Department left the details of the work to the judgment and experience of the company, who, naturally, wanted to make the work as successful as possible. The fact that only one company out of seven cared to undertake the work, although all were busily engaged at the time in street or house lighting, or both, goes to show that ship lighting is quite a separate branch of the general subject of electric lighting, and that these companies did not care to start on an experiment in which unusual difficulties were to be encountered and the commercial success of which was questionable, or at least uncertain.

The executive officer of the Trenton, Lieutenant-Commander Bradford, an officer who had interested himself in the subject of electricity and electric lighting, was ordered to her some time before the ship went into commission for duty connected with the installation of all the electrical apparatus. The plant was installed during the summer of 1883, and in September of that year it was started into regular operation, a careful record being kept of its performance under all circumstances, and reports submitted from time to time to the Navy Department. It was in operation throughout the full three years' cruise of the ship, and in spite of the fact that it was the first plant to be put on board of one of our vessels of war, that the officer in charge and men running it had no previous experience, and that many difficulties were encountered for these very reasons, the lighting of the Trenton by electricity was an undoubted success. More than that, it confirmed what had by this time been learned abroad, that no modern war vessel is complete without a plant for lighting the ship by electricity.

---

* While the Trenton was the first man-of-war to be lighted by electricity, the U. S. Fish Commission Steamer Albatross, built under the direction of a naval officer, and officered and manned by the Navy, received her electric light plant in 1882. The plant consists of an Armington and Sims engine, driving an Edison Z dynamo, to operate 120 eight-candle B lamps or their equivalent; there were 136 lamps in place. There were two main double circuits, one leading forward and one aft. Dr. Moses's arc lamp was frequently on this circuit, using the current of about twenty lamps.

The Trenton had what is known as a single plant only; that is, one dynamo machine and one engine; so that if anything happened to them, necessitating their stopping, oil lamps and candles had to be resorted to. This necessitated the vessel being supplied with a full allowance of lamps and candles. The next vessel to be supplied with an electric lighting plant was the Omaha, which was fitted out in the summer of 1885. By this time the various companies had begun to give the subject of ship-lighting some study and attention, as a growing business, and several of them were prepared to undertake the work. The Navy Department prepared the specifications and asked for bids in October, 1884, and the work was awarded to the Consolidated Electric Light Company (the Sawyer-Man system), that company submitting the lowest estimates. The plant was considerably smaller than in the case of the Trenton, and the Bureau had the experience gained with that vessel to use as a guide. The Omaha has now been in commission nearly two years, and the commanding officer reports that the plant has uniformly worked well.

This brings us to the first of the new vessels authorized by act of Congress in August, 1882, the Dolphin, Atlanta, Boston, and Chicago. In the case of the Dolphin, the contract required that she should be turned over to the Government complete, except armament, so that the electric lighting plant was put in by the contractor. The Advisory Board selected the fixtures, and made certain requirements in regard to the number of lights, the location of the dynamo, kind of wire to be used, &c.; but the contractor was free to select whatever company he chose to do the work. He selected the Edison Company, and when the vessel was turned over to the Government the plant was already installed and ready for running. In August, 1884, the Edison, Brush, and United States Electric Lighting Companies were invited to submit proposals for lighting the Atlanta and Boston, the Department reserving the right to award the contract for one or both vessels to the same or different companies. The United States Company (Weston system) was the lowest bidder and was given the Atlanta's plant.

In order that there might be two systems in the two ships, the Brush Company agreed to install a plant in the Boston for the same price as that for which the contract for the Atlanta was awarded. The Department was thus enabled to have experience with four different systems. Owing to the delay in completion of the Atlanta and Boston, work on the plants for these vessels was not started until 1885, and in October of that year, Lieutenant-Commander Bradford was ordered to superintend their installation; and in January, 1887, he was ordered to duty under the Bureau of Navigation as "Inspector of electric lighting of ships of the Navy," and took charge of the office of "Naval Inspector of Electric Lighting."

The establishment of such an office was a wise measure. Copies of all letters and reports from vessels and stations on the operation of plants in service are forwarded to this office, where they can be properly filed and their contents noted and digested. Specifications for the lighting of new ships can be drawn up intelligently and systematically, advantage being taken of the experience gained with plants already in use on shipboard, and of the latest improvements in engines, dynamos, wires, lamps, &c. The Inspector can address the various companies, learn their capacities in regard to ship lighting, and make suggestions; in short, by creating a healthy competition, make it an object for them to develop and improve the installation of ship's plants in every way possible. The information so collected forms a valuable collection of papers on the subject, and enables the Department to keep itself posted on all the latest inventions and improvements. It was through the courtesy of this office that most of the data for this paper was obtained.

In considering the subject of lighting ships in detail, the first question to be decided is what shall the plant be, it being known that a certain fixed number of lamps, of a certain candle-power, will be required to light the ship properly, and that sufficient power must be furnished to supply these lamps. As already stated, the Trenton, Omaha, Dolphin, Atlanta, and Boston were each fitted with a single plant, *i. e.*, one engine and one dynamo only, capable of running all the lamps. This necessitated a full allowance of oil lamps, to be used in case of accident to the engine or dynamo. Again, a single plant can not be run all the time; the engines must have rest, and oil lamps must then be used below, in the engine and fire-rooms, orlops, store-rooms, and holds, during the daytime.

The specifications for lighting the new vessels authorized by Congress in 1885 and 1886, as well as the Chicago and monitors, call for "two complete plants, each of which shall be an exact duplicate of the other in every respect." It was suggested at first to have in these ships two dynamos, but of different sizes; a large one, capable of supplying light to the lamps used at night, and a smaller one for running the comparatively few lights required in the daytime. The advantages of two *duplicate* machines over such an arrangement are well put by the Inspector of electric lighting, as follows:

(1) If the dynamos are of different sizes, although they may be of the same electro-motive force, if that of the larger one be accidentally low-

ered, the smaller may be overloaded, unless carefully watched. This applies, of course, when both machines are in operation, as would be the case during the earlier part of the evening, when the greatest number of lights are in use.

(2) A small dynamo cannot supply the lamps actually needed at night. If, therefore, anything happens to the large machine, oil lamps must be used. This upsets one of the principal objects of a double plant, the ability to depend entirely on electricity for illuminating purposes.

(3) Two dynamos of equal size are each large enough to light the ship well, while both together can operate all the lamps, or as many as may be needed in the early evening.

(4) There is no economy in small dynamos, beyond the first cost, as all dynamo engines now have good governors, which regulate the supply of steam according to the load.

(5) With duplicate plants the number of spare parts carried can be diminished.

It seems desirable that the lighting of vessels by electricity should be entirely under one control, as tending to promote the efficiency, economy, and usefulness of the plant. The Atlanta is a case in point. The illumination of the ship by the incandescent lamps is under the Bureau of Navigation, and for this purpose one dynamo is provided, suitable only for operating incandescent lamps—what is known as a "shunt-wound" machine. The Bureau of Ordnance has charge of the electric search lights, of which there are two, and provides a "series-wound" dynamo for each light, a direct-coupled Brotherhood engine being used to run them. All three dynamos and their engines are in the dynamo room on the berth-deck. The incandescent dynamo will not operate the search lights and the search-light dynamos do not develop sufficient electro-motive force to run more than about fifty incandescent lamps. If the Atlanta were supplied with two "compound-wound" machines, instead of the three she now has, one machine could be kept running all the time to operate the incandescent lamps, and when it was desired to use the search lights one machine could be used for them. A compound-wound Weston dynamo has recently been ordered for the torpedo station, which has an output of 200 ampères at 80 volts electro-motive force, and which is to run two hundred and thirty 16 candle-power lamps or two search lights (such as the Atlanta has), with a reserve for incandescent lamps. In regard to this last, it is doubtful if incandescent lamps can be operated satisfactorily on the same circuit and *at the same time* as a search light, for the variations in the resistance of the arc of the latter are bound to affect the steadiness of current, and hence of the lamps. The torpedo station has also ordered a boat dynamo to run two boat search lights, two 100 candle-power incandescent lamps, and thirty-two 16 candle-power lamps or their equivalent. The dynamo is run by a modified Westinghouse engine (direct-coupled), engine and dynamo weighing 700 pounds and occupying a cubic space of 40 by 28 by 28 inches. Such a machine could be utilized on a vessel having only a single plant for running the lamps required in the daytime on board the ship, and would be more useful than a dynamo capable of running the boat search light only, such as the Atlanta has.

The best arrangement of plant undoubtedly is to have two or more dynamos exact duplicates, each with its own engine and so arranged that either engine may run either dynamo. It may be that in large ships, such as the 6,000-ton armored vessels for which plans have just been submitted, so many lights will be needed that three or even four dynamos will be necessary to run all the lights, unless they are made very large, which is undesirable. This arrangement of a "gang" of several dynamos would be the most economical, since only as many need be run as are required for the light used at different times during the day. As to the methods of coupling the engines to the dynamos, more will be said later. The number and size of the dynamos required for any ship must depend upon the number of lights put in.

In settling upon the size of the plant, then, it is first necessary to take the plans of the ship, or the ship herself if already built, and locate each lamp she is to have. This is a long piece of work, and requires care and thought on the part of the Inspector. He must not only decide how many lamps are needed to light the ship thoroughly, but also the exact position of each lamp, its style of fixture, and its candle-power, for in many places a 10 candle-power lamp will answer just as well as one of 16 candle-power, the difference being so much work saved for the dynamo. All specifications for lighting ships are, at present, accompanied by a list, giving the grouping of lamps into circuits (and the number on each circuit), the position and candle-power of each lamp used on the ship, and the kind of fixture for each lamp. For convenience in handling the lights, to prevent a break in one place on a circuit putting out all the lamps, and to avoid the use of such large wire, a ship is usually divided into a certain number of sections for lighting purposes. As an example, we will take the Chicago, having thirteen; that is, there are thirteen circuits that start from the dynamo room and run to the different parts of the ship, each circuit being controlled by a separate switch in the dynamo room, and being entirely independent of every other circuit. This arrangement has three advantages.

(1) If there is a break or bad ground on one circuit, it can be shut off at once and the rest can still be used.

(2) Lights in certain parts of the ship, as for example the orlops and holds, can be controlled from the dynamo room, so that there can be no unauthorized lights below, and such circuits can be turned on and off at fixed times.

(3) Those circuits having comparatively few lights on them and hence a small load to carry, require less copper in them, that is of smaller size, and thus effect a saving in cost of wiring.

The Chicago is to have lamps of 10, 16, 32, and 50 candle-power, all interchangeable on any one circuit, with an independent control over each lamp. The following is the arrangement of her sections:

Number of section.	Location of section.	Number of lamps.	Total candle power.
I.	Forward orlop and hold	36	448
II.	After orlop and hold	33	472
III.	Coal-bunkers	30	300
IV.	Boiler compartment and engine rooms, starboard	37	552
V.	Boiler compartment and engine rooms, port	37	558
VI.	Berth deck, starboard forward	31	466
VII.	Berth deck, port forward	31	460
VIII.	Berth deck, starboard aft	25	388
IX.	Berth deck, port aft	24	366
X.	Gun deck, starboard	32	500
XI.	Gun deck, port	33	498
XII.	Gun deck; officers' quarters	33	528
XIII.	Spar deck	26	566
	Total	408	6,102

The following is the number of lamps of different-candle power:

	Number of lamps.	Candle power.
10-candle power lamps	121	1,210
16-candle power lamps	275	4,400
32-candle power lamps	6	192
50-candle power lamps	6	300
Total	408	6,102

In other words, having located the lamps and fixed their candle-power the total is found to be something over 6,000. Accordingly the specifications call for *two* dynamos, each of which shall possess a capacity of *at least* 3,200 candle-power of light, so that with both dynamos in operation more candle-power can be supplied than is required when every light is in operation (something that rarely happens, by the way). This allows a certain necessary factor of safety, for a dynamo cannot be overloaded any more than a steam engine or a boiler.

THE ENGINE.

The style of engines to be employed on board ship for running the dynamos is important. On shore the usual, in fact the almost universal, practice is to have the dynamo belted up to the engine. The reason for this is that dynamos now made are usually designed for a high speed of armature, 1,000 turns a minute, or more, and with an engine making 280 to 300 revolutions it is an easy matter to attain the required armature speed by varying the size of the driving pulleys;

further, such engines are cheaper and more common than direct-coupled engines. On board ship, however, two points which have but little weight on shore must be considered in the installation of a plant viz., *floor space* and *weight*, two important points in a man-of-war. With the new cruisers authorized by Congress in 1885 and 1886, for instance, the various elements entering into their design claim their allowance of weight and space to the last pound and foot, and everything should be made as light and compact as possible. The style of engine best suited for ship use is undoubtedly one that couples direct to the armature shaft of the dynamo. It will not be possible to use a high-speed armature with such an engine, but the various lighting companies can design low-speed armature machines if there is any demand for them; in fact they have already done so. Dynamos with low-speed armatures are already largely used in English men-of-war and merchantmen in connection with a direct coupled engine. To show the advantages of the latter we will compare the Atlanta's plant with that recently installed on board Mr. Vanderbilt's new yacht, the Alva. The Atlanta has a 150-light shunt-wound Weston dynamo, designed for an armature speed of 1,250 revolutions per minute and belted to an Armington and Sims engine, making about 300 revolutions per minute; the floor space required for engine and dynamo is 17′ 5″ × 6′; weight, 6,500 pounds. The Alva has a 160-lamp compound-wound Siemens machine, armature designed to make 450 turns a minute, driven by a direct-coupled Willans engine; the floor space required is 9′ × 3′, or about one-half that of the Atlanta, and the weight is 6,048 pounds. In addition, the Alva's machine is capable of running a powerful search light on the topgallant forecastle of the yacht. The entire plant was put in by Siemens Brothers of London, and it is understood that this arrangement is being extensively introduced into the English navy. Our own companies, however, can supply just as good and even better plants if the Government asks for them, and it is to be earnestly hoped that our new vessels now building will be supplied with direct-coupled engines, otherwise it may be difficult to find sufficient room for such a plant as they should have.

The latest information from abroad is that English and French ships are now using *compound* vertical direct-coupled engines for driving dynamos, and that economy in *fuel*, as well as in space and weight, is required. In the English navy the standard speed for dynamos is now about 400 revolutions per minute; and in the French navy about 350 per minute. In merchant steamers direct-coupled engines are not considered so essential, those with rope belts and friction gearing being largely used; but this applies only to large vessels having plenty of room.

THE DYNAMO.

With the ships now building, the firm which contracts to build the vessel gives the lighting to any company it may wish. No matter who does the work, however, the plant must conform to the specifications, and it must be run for a week by the company before it is turned over.

The Naval Inspector of lighting vessels has supervision of the work, from the time the installation of the plant is started; he inspects it regularly, and it must be satisfactory to him before being accepted. The inspection, by an officer, of the work as it progresses insures to the Government good material and good workmanship. Improvements are constantly being made in the construction of dynamos, lamps, wires, everything connected with a plant, and the latter should not be put into a vessel until the last moment—until the ship is nearly ready to be turned over by the contractor. The specifications for new vessels require the plant to be the lightest and most compact that can be obtained in the United States at the time it is put in, and with an average life of 600 hours per lamp, it must produce at least 125 candle-power for every mechanical horse-power exerted. Economy of weight and space are mentioned as being *very important*, and with double plants the engines must, if possible, be so arranged as to drive either dynamo. Each engine must be capable of driving one dynamo at full power with a piston pressure of 40 pounds per square inch while exhausting into the atmosphere; and they will both be fitted to exhaust into a condenser or into the air. This condition is necessary because the pressure of the steam supplied to the engine will vary greatly; when underway, with steam on all, or several, of the boilers, the pressure will run up to 100 pounds or more per square inch, while in port, with steam on one boiler only, the pressure will vary from 40 to 70 pounds. When underway, the engine can always exhaust into a condenser; but in port, although the vessel may have an auxiliary condenser, as the Atlanta has, it is not always in use, and hence an atmospheric exhaust is provided.

In regard to dynamos, the specifications state how many there shall be and the total power they will be called upon to exert, which will depend simply upon the total candle-power of the lights used. They must be so constructed as to permit the use of lamps of 10, 16, 32, and 50 candle-power (or groups of lamps of equal candle-power) on the same circuit, with an independent control over each lamp or group. This is done, as has been shown, to permit the use of lamps of different candle-power about the ship, thus reducing considerably the total candle-power required of a machine. "In addition to all necessary attachments for operating the plant, such tools, wrenches, speed indicators, steam-gauges, oil-cups, drip-pans, guards, hand-rails, oil-cans, and feeders as are necessary in its care and manipulation, all of which must be specified in the proposals, shall be supplied." This clause in the specifications is an important one. In the earlier specifications for lighting vessels many of these articles were omitted, from want of practical experience, and as they are all necessary for the proper running of a plant, considerable inconvenience has been caused. Two more things should be added to this list of "accessories"—a volt metre and an ampère metre, the former for measuring electromotive force; the latter, strength of current. Without these instruments it is impossible to test the efficiency or other qualities of a dynamo, except a rough estimation of the candle-power developed by the lamps, and determined by the relative brilliancy which a lamp appears to the eye to have.

Having considered the *kind* of plant best suited for a man-of-war, the next question to decide is where the plant shall be placed on board ship. Unquestionably it should be below the water-line, as far as possible out of reach of an enemy's fire. In fact, in a ship with a double plant, where oil-lamps should be done away with entirely, the dynamo room becomes one of the vitals of the ship, and as such should be as thoroughly protected from hostile fire as any other vital part. In all of our vessels at present supplied with electric-lighting plants, the dynamo room is situated on the berth deck, above the water-line, where a single shot from a machine gun might, on entering, disable the whole system; and when these ships were to go into action it will be necessary to have every oil-lamp in place and lighted, for the dynamo would probably be placed *hors de combat* in a very few moments. In every vessel there are many store-rooms below the water-line which could be made to change places with the dynamo room, and this should be done. The sail rooms, for instance, could easily be utilized for this purpose.

THE WIRING.

This is one of the most important things in the installation of a plant and should be carefully considered, for upon it depends largely the economy and efficiency of the whole system. In wiring a building on shore, no special precautions are necessary, for the wires are well protected from weather, water, chafe, &c., and need never be taken down when once properly put up. On shipboard it is different. The circuits, as well as the machines should be below the water-line, or at least under the protective deck, as far as possible. If the dynamo room is below, where it should be, the important circuits, those for the magazines, shell rooms, engine, and fire rooms, will naturally be below the water-line also. Wires so placed will not be quite as accessible for inspection or repairs, but they will be safe from an enemy's shot, which is much more important. Where they run above the water-line, as they must for the lights on the upper decks, there should be as few fore-and-aft leads as possible; that is, the mains should be kept below, and vertical branch circuits led up as required, thus obtaining minimum exposure to fire. The greatest enemy to the wires of a ship, however, is not a hostile shot, but sea-water, the supply of which never runs short. When the Trenton was wired this difficulty was only partially appreciated, and much trouble was experienced during her cruise. Her main circuits were inclosed in wooden battens (as they are in all vessels), with two grooves in them for the wires, and a cap piece screwed on to the bottom of the battens. They were well painted and puttied and were fairly water-tight. For branch circuits a small molding with two grooves in it was simply screwed against the bulkheads or beams, and water worked its way in behind the moldings easily. The copper conductors of the *mains* were *tinned*, but the smaller wires were not, and the action of the salt water on them was remarkable. The cotton insulation of the branch wires was soon rotted away, and the water on reaching the untinned wire, attacked and corroded it off; after the corrosion, a greenish powder remained, retaining the form of the wire, which seemed to be sensitive to heat, and which, on the passage of a current of electricity would ignite, setting fire to the wooden molding, sometimes without the current being sufficiently strong to burn out the "safety plugs" on the circuit. Sometimes the wooden molding would be found only blackened and charred. This thing happened several times during the earlier part of the cruise, and shows the importance of (1) having all wires *tinned;* (2) having the best insulation that can be obtained in the market; and (3) having the moldings, or battens, and lamp fixtures as water-tight as they can be made. The trouble experienced with the Trenton was a valuable lesson, which led to a careful investigation of the wiring of ships, and all the later vessels are much better wired. The Omaha, Atlanta, and Boston have lead-covered wire throughout, and the insulation is better than in the Trenton, consisting of a layer of cotton thread, then rubber, then a jute braiding, and finally the lead covering. The latter is not part of the insulation, but is put on to protect the insulation from chafe, from the attacks of vermin, and from the injurious effects of heat or water; it is necessary to lead the wires in some places where the air is hot and dry, and without the lead covering all moisture is soon driven out of the insulating material, which cracks and breaks away from the copper conductor. Much trouble has been experienced with lead-covered wire on shore and the cause assigned to the lead covering, when the trouble was with the *poor insulation* under the cover. The disadvantages of the lead cover are (1) it makes the wire more expensive; (2) if improperly put on (or impure) it cracks and breaks away from the wire when bent; (3) the wire is harder to manipulate. If, however, the insulation of the wire is good, the lead pure and well put on, the lead-covered wire is much superior to any other, at all events for ship use.

In regard to the insulation proper, it would seem that the best is rubber only, as salt-water in the course of time rots any cotton thread or jute braiding. Specifications now issued require *all* wires to be of tinned copper, of a conductivity not less than 96 per cent. (that is 96 per cent. pure copper), with the best rubber insulation, and a pure lead covering outside of this. The lead covering is submitted to a chemical test for purity. No wire larger than No. 16 B. W. G. (0.02 in diameter) is allowed in any conductor; if the conductors are larger than this they must consist of a "bundle" of smaller wires, not one large one. This is done to make the wire flexible and easier to handle; the insulation is also less liable to break. Before being put in a ship, all wires are required to pass a satisfactory insulation test: A sample, not less than 500 feet in length, is immersed in sea-water, and after *at least* twenty-four hours' immersion it must possess an insulation resistance of not less than 1,000 megohms per nautical mile. A wire that will stand this test is a good one, and may safely be used on board ship.

The size of wire varies according to the current it has to carry; the branch wires leading to a single lamp, for example, can be much smaller than the main circuits, supplying current for thirty or forty lamps. A coefficient of safety is always used in figuring out the size of wire required; that is, it is always of such a size that it can carry safely more than the normal current for that wire. The rule adopted for wires for our vessels is that they shall have a conducting area not less than one square millimetre per one and a half ampères of current, or one square inch conducting area per 1,000 ampères. Either of these rules allows a good factor of safety.

It sometimes happens that on account of a leak or short circuit in a wire, caused by defective insulation or otherwise, the current on that circuit is abnormally increased, and if no precautions were taken, the wire might be fused or burnt out. To provide against this, a *safety strip*, or "fuze," as the English call it, is introduced in the main circuits, wherever the branch wire runs off to a lamp or group of lamps, inclosed in a water-tight box. This safety strip consists of a piece of soft fusible metal, fusing at a low temperature, and of such a diameter that a strength of current sufficient to endanger the wires will fuse the strip, breaking the circuit of that branch, and thus saving the wire; it only requires the insertion of a new strip, then, to make the circuit good again. It is important that the boxes in which the safety strips are inclosed should be absolutely water-tight. The boxes on board the Atlanta are of bronze, secured to the deck overhead or to a bulkhead by screws passing through flanges cast on the bottom of the box. The wires enter the box through stuffing boxes on the sides, which are supposed to be water-tight. The top of the box is closed by a cover screwing down on a rubber gasket, and Fig. 1 shows the connections inside of the box.

In two cases salt water has worked its way inside these boxes, presumably by running along the wires through the stuffing-boxes; in one case the dynamo was running and the inside of the box was entirely destroyed, the binding posts being almost melted away, and the wood-work around the box being scorched by the flames; there was no trace left of the safety-strip. In the other case the dynamo was not running, fortunately, but the box was found half full of water, causing a bad ground on the circuit. These boxes should be so tight that a hose could be played on them and no water get in. If they leak, it is better to take the covers off altogether, so that the water can be seen if it gets in. Otherwise the first warning of its presence is the burning out of the box and a heavy sparking at the dynamo, which is very injurious to the commutator.

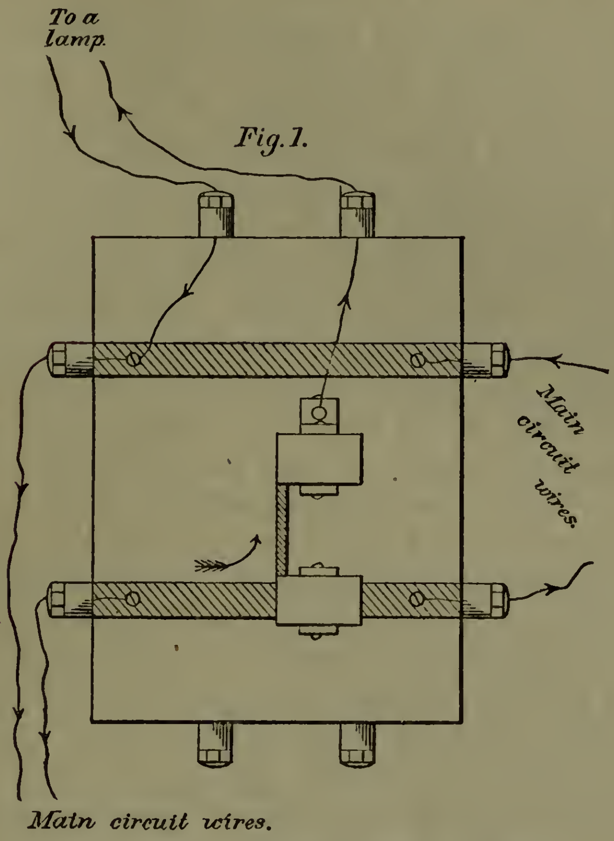


Fig. 1.

NOTE.—Arrow-heads show direction of current.

The fact that water got into the two boxes mentioned may have been due to the glands on the stuffing boxes not being set up sufficiently, but at all events it shows how much harm water can do if it does get into a box.

Splices are apt to give trouble in wires unless carefully insulated. Formerly they were not mentioned specifically, but now whenever a wire is tapped to make a joint with another wire, the joint is required to be soldered, then insulated (with rubber tape or something of the kind), and the joint inclosed in a water-tight box. Another place where water is liable to cause trouble is where the wires of a branch circuit enter the fixture of a lamp; the water runs along the wires, enters the socket holder, and perhaps the lamp itself, and when the circuit is made, the socket or lamp, perhaps both, are burnt out by being short circuited. The fixtures of the Boston and Atlanta about the decks are generally secured to a pine board about half an inch thick. The joints where the fixtures rest against the wood have been made as tight as possible with putty and paint, but they are not water-tight, and care has to be taken, especially on the upper decks where water is used freely, to keep these joints dry. If water does get into the socket, as it has more than once, there is nothing to do but dispense with the services of the lamp until the socket is dried out. All apertures by which wires enter a fixture are now required to be closed by a water-proof compound of some kind, so that no moisture can get at the socket or lamp. Wherever wires pass through a water-tight bulkhead or deck, the openings are required to be made water-tight by suitable glands or stuffing boxes.

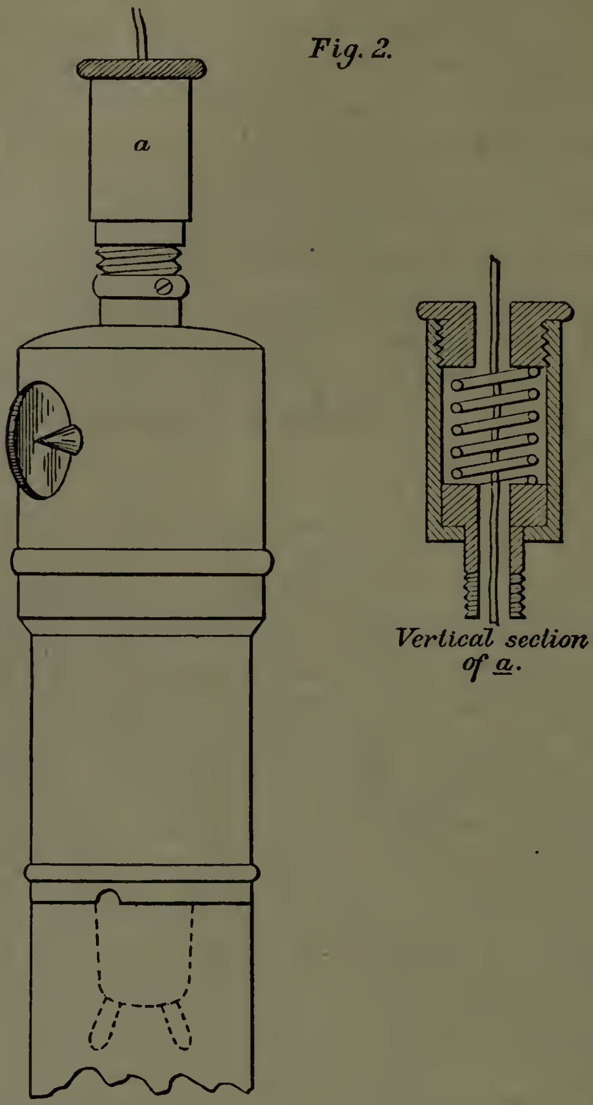
With a vessel built entirely of steel, as all modern vessels now are, the ship herself is a good conductor of electricity and can be used as a return or "earth." Siemens ship plants are wired in this way, and the Alva before mentioned is similarly arranged. The negative pole of the dynamo is connected to a brass plate, 6 by 3 inches, soldered and secured to the ship's side; one wire from each lamp is then secured to some neighboring iron work of the vessel by a brass screw, tapped into the metal and then white leaded, so that the ship acts as a return lead. This system of wiring is very objectionable, from the fact that if there is a leak on any circuit, and such leaks are liable to occur any day, a short circuit is immediately established to the machine, and might result in the burning out of the armature, or at least cause such sparking as to injure the commutator seriously. It has been the invariable rule in our vessels to use return wires on all circuits. The dynamo, junction boxes, lead covering of wires, joints, splices, in fact the whole system, is required to be insulated from the ship itself, and all joints, fixtures, switches, and boxes must be water tight. With the system complete, and connections of every lamp ready for use, the insulation resistance of the whole system, including the dynamo, must be at least 1,000 ohms per volt of electro-motive force developed by the dynamo. That is to say, if the machine develops an electro-motive force of 100 volts, then on connecting the wires of a Wheatstone measuring bridge, one to one pole of the dynamo, the other to any iron work of the vessel, the resistance so measured must be not less than 100,000 ohms. With return wires there may be short circuits established between parts of a circuit or between different circuits by the wires grounding, but the dynamo, the source of power, is not injured.

In all wiring, some regard should be had to accessibility. The wires should be protected as far as possible from an enemy's fire, this is the most important point; but after this they should whenever possible be led where they can be got at. No matter how much care is taken when the wires are put up, grounds and leaks will occur from time to time, due to one cause or another, from the battens containing the wires being hit or crushed, the insulation being knocked off, &c., and such faults should be repaired at once upon being discovered. The battens should never be led behind paneling or ceilings, where it is necessary to rip the woodwork down to get at the wires, nor in grooves or gutters where water is liable to lodge. They should always be in plain sight when possible; and it is now required that they shall be of the same material and finish as the woodwork in the immediate vicinity. Except in the officers' quarters (where the battens may be of hard wood), they should be well painted and puttied as soon as put up, to make them as water-tight as possible. Care should be taken in screwing on the cap pieces of the battens. On some of the circuits of the Atlanta grounds have been discovered that were caused by the screws that hold the cap piece having been screwed right through the insulation of the wire, so that they touched the copper conductor and made connection between it and the steel bulkhead or deck. This was due, of course, to carelessness. Again, the lead covering of the wire has been found broken, and the bare wire exposed, where a wire has been bent to go through a water-tight bulkhead, so that the copper made contact with the steel.

THE FIXTURES AND LAMPS.

The lamps for a vessel are furnished by the company who install the plant and are those ordinarily used with the company's system. Four years ago there was only one company in this country able to furnish incandescent lamps of different candle-power to be used in the same circuit. It was a question which had received but little attention, and there were several difficulties to be overcome, such as the adjusting of the resistance and length of the carbon loop for a lamp of higher power, to the electro-motive force of the dynamo, and the strength of current required for the lamp. Within the last two years, however, the problem has been solved, and at present all of the principal lighting companies are prepared to supply lamps of four (or more) different candle-powers to burn on one circuit. It has already been shown that such an arrangement is desirable on board ship, where a considerable saving can be effected by using lamps of different candle-power. Other things being equal, that lamp which is shortest and most compact is best suited for ship use. In some places the lamps are unavoidably so put up as to be more or less in the way of passers by, and every additional inch of length increases the chance of the lamp being hit and broken. Again, the longer the carbon filament is the more sensitive it is to vibrations and shocks, which are inevitable on board ship. On the Trenton it was found that the expenditure of lamps in fixed brackets and electroliers was much greater than in the case of the portable holders, which can be moved about to stand on the deck or table. The Trenton had the Edison lamps, and with these the connection between the lamp and its socket is a rigid one, allowing no play of the lamp at all, and it was thought that the vibration of the filament, due to the propeller and motion of the vessel, caused it to break. To overcome this, spiral springs were attached to the sockets of lamps in fixed brackets, as shown in Figure 2, so that the springs might take up the vibrations to a certain extent, thus saving the filament. This arrangement was found to work admirably, and similar ones have since been put on all lamps that are in fixed brackets.

Fig. 2.



The Atlanta [illegible] supplied with the Weston 16 candle-power 110-volt lamp throughout, which, for its candle-power, has a carbon as long as (if not longer than) any other style of lamp. The lamps are supplied with the spiral-spring attachment, and in addition they make contact in the holder on springs, which also permits a certain play. It has been found that in about one-half of the lamps expended since the plant was started the filament has been broken, not burnt out, usually where its ends attach to the platinum tips of the lamp. The filament is 3 inches long and very fine, and the slightest jar to the lamp sets the filament vibrating violently. In many cases it has been broken while the lamp was being cleaned, although the latter was handled as carefully as possible. This experience is something new, and shows that the filament should be shorter, or else of such a shape as to be less sensitive to vibration.

A somewhat remarkable thing happened in the case of a lamp in a horizontal position in an ordnance store-room: It was noticed that the carbon loop began to curl downward, as the life of the lamp increased, until finally one day it touched the glass; the latter being heated and expanded at one spot, broke and destroyed the lamp. This bending down or sagging of the loop is observed, to a greater or less extent, in all lamps which are in a horizontal position, but only in the case mentioned has it been so great as to make the loop touch the glass.

Out of eighty-five lamps recorded as having been broken on board the Atlanta up to March 30, 1887, only six or eight have had the glass broken. It is the carbon loops that break, and in view of the fact that they are so sensitive to shocks or vibration, the Department has directed that the behavior of the lamps be carefully observed with the ship in motion and when the guns are fired. It may be that owing to the play which the lamp has on the springs in its socket the spiral spring attachment in *this case* is unnecessary; in fact, it may be a positive disadvantage, as tending to set up vibrations of the filament too readily, and so cause it to break.

The location of the lights is an important question, and requires careful study. The object is to get the greatest amount of light with the fewest lamps; but they must be out of the way as much as possible, and there are places where they cannot be put; so that a careful study of the plans of the ship is necessary to obtain the most effective arrangement. As a rule, the higher the lights are put the more effective they are, as the white ceiling or deck overhead throws the light down; but on the decks, where the men sleep, the lights would be directly in their eyes if placed overhead, and they are accordingly put on the sides of the ship, or on bulkheads, masts, stanchions, &c., so as to be a foot or two below the hammocks when swung. In all store-rooms, holds, and orlops the lights are placed either on the deck overhead or on a bulkhead close to its upper edge. They are then out of the way and less liable to be hit or broken. For officers' quarters a certain number of fixed lights overhead are usually provided, and for reading or writing a portable frame-work and holder, with 6 or 8 feet of wire attached, which can be placed on a desk or table and moved about as desired. The naked light is rather trying to the eyes when it is used for any length of time, on account of the blinding effect of the incandescent filament, and an opal or etched glass shade is therefore provided to go over the lamps in the officers' quarters and offices. Lately, too, lamps are made of ground glass, which softens and diffuses the light and makes it much more pleasant. For the officers' quarters the electroliers, brackets, and fixtures used are more or less ornamental in design and are of brass, silver-plated. Nickel-plate was used in the first ship, but this soon wore off with rubbing and looked very badly.

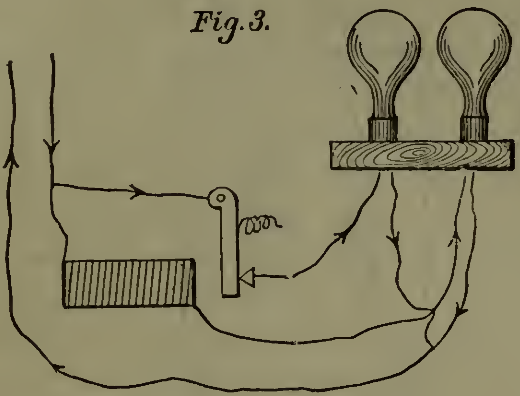
About the decks, holds, orlops, engine, and fire-rooms a guard of some kind is absolutely necessary for the lamps, and the fixtures have to be as compact as possible. A short brass silver-plated arm, with the socket for the lamp attached, is the usual kind of fixture for these places, the arm being secured to a wooden baseboard or to the woodwork of the ship. If the lamp is to be vertical, this arm is bent to a right angle. On the Atlanta and Boston box-shaped guards, with glass sides and fronts protected by wires, are used in many places. The tops and bottoms of these boxes were solid, and it was found that they cut off much of the light from the lamps and were not water-tight. The bottoms of the boxes were threfore cut out, and the light thrown out on the deck was increased 50 per cent.

The best guard is a plain, open mesh of wire, bent so as to surround the lamp and hinged on one side to the board or bulk-head to which the fixture is attached. They should be strong enough to withstand a good blow, and they are now required to be of one-eighth to one-quarter inch (according to the location of the lamp) galvanized iron wire, with a mesh 1½ to 2 inches square. They are compact, protect the lamp well, cut off but little light, and the lamp is always accessible for cleaning, &c. In some places, such as the engine and fire-rooms, coal bunkers and shaft alleys, a steam-tight glass globe is put around the lamp inside the wire guard; they are made of heavy glass one-eighth to one-sixteenth inch thick, and are impervious to steam or water.

For deck lights and signal lanterns the ordinary deck lanterns are used without the glass globes, the sockets for the lamps being secured to the top lids of the lantern, and the wires led through the lids. A length of 20 or 30 feet of wire is attached to the lantern, so that it can be carried about the deck, and a box is put up near each gangway or wherever the light is to be used, having in it three or four sockets for connecting the free ends of the lantern wires. When not in use the wires are coiled around the lanterns and the latter stowed below. The electric side and headlights consist of the ordinary lanterns used with oil lamps, but each lantern, instead of the oil lamp, has in it two incandescent lamps so arranged that in case one is broken or burnt out the other immediately becomes active. Fig. 3 shows how this is accomplished. There is a small electro-magnet (of low resistance) in the circuit of one lamp, Fig. 3, while the circuit of the other lamp is made through the armature of the magnet and the metal stop against which the armature is held by a small spring. The current being thrown on, part of it goes through the magnet coils, and the magnet becoming active draws the armature away from its contact stop and so breaks the circuit of that lamp. As long as the first lamp is burning the armature is held away from its stop; the moment, however, the circuit of this lamp is broken from any cause, the magnet ceases to attract the armature and the latter flies back to its stop, thus completing the circuit of the second lamp. This apparatus works well and seems to be reliable.

The side-lights are connected to sockets near them by short lengths of wire. For the head-light and top-light (for a flag-ship) the wires have to run up the masts, of course. On the Trenton they were inclosed in a brass tube. Trouble was experienced with these circuits and they were finally taken down, tube and all; the insulation of the wires was rotted off in places, and showed that water had evidently got into the tube and lodged there. The opinion of the officer in charge of the Trenton's plant was that such a tube should never be used to inclose the wires, as they can never be examined without disconnecting them and taking tube and all down; and if water gets into the tube there is no way for it to get out. In fact, if the insulation of the wires is such as it should be and with a lead covering, it is thought that the wires on the upper deck should be left uncovered; that is, instead of having a cap piece on the moldings which hold the wires, have the wires kept in the moldings by wooden buttons or strips of tape at intervals. Then if water gets into the molding, as it is very liable to on the spar deck, it can run or be dried out.

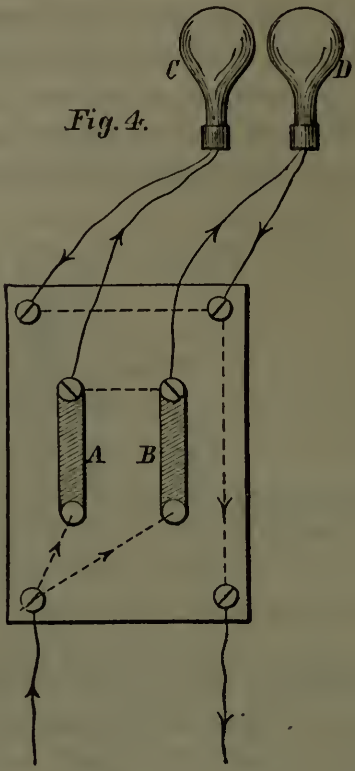
Fig. 3.



For magazines and shell-rooms a portable lamp is put in the light-box, the wires leading through a short piece of brass tubing in the top of the box and tapping into the nearest circuit. One 16-candle-power lamp will light a shell-room or magazine thoroughly and make it much more cheerful than formerly.

For night signaling, an apparatus was gotten up on board the Trenton to use a couple of incandescent lamps, in connection with Myer's signal code, which worked very successfully. One lamp was flashed to make "1" and two lamps for "2," and Figure 4 represents a key-board with the connections made, showing how this can be done. A and B are two brass keys, each making contact on a metal stud underneath them when pressed down. The permanent connections are shown in dotted lines. It will be seen that by pressing *A* the lamp *C* only will be flashed, while by pressing *B* both lamps are flashed. To make "3" of the signal code, either a time interval could be introduced between words, or another lamp and key added, so that on pressing the key three lamps would be flashed. The lamps are hung upon a stay or spar, at a distance apart depending upon the distance between the signaling vessels, and the wires to the key-board make connection in a socket placed in some convenient place near the signaling stay or spar.

Fig. 4.



Another novel use to which the incandescent lamp has recently been applied, and one that promises to be an important one for naval purposes, is the lighting up of the water below the surface at night-time. Experiments have recently been made at the torpedo station with incandescent lamps of 100 or 150 candle power on the ends of torpedo spars submerged to distances varying from 5 to 15 or 20 feet, and the results have been most satisfactory. The water is lighted up so that objects in it can be distinctly seen within a radius of 100 to 150 feet or more, while there is little or no glare above water to betray a boat's presence. A boat rigged in this way might be most useful for countermining an enemy's field of submarine mines, by enabling the men in the boat to discover the mines and either sweep them to one side or cut the cables. If the lamp is turned on before it is immersed, the glass is cracked and broken as soon as it touches the cold water, but by turning on the lamp *after* immersion, the heat generated is carried off by the surrounding water, and the lamp is not cracked at all. It is probable that our torpedo launches will be supplied with lamps for this purpose in future.

An elaborate plant having been installed in a vessel, the question arises as to who is to be responsible for its care. About two years ago a course of instruction was laid down for certain enlisted men of the Navy by the Bureau of Equipment and Recruiting. The idea was to take about fifty men, holding continuous-service certificates, and send half to the Washington navy-yard and half to the torpedo station, changing them about at the end of six months. At the end of a year, if they passed a successful examination, they were to be qualified as "seamen gunners," and a certain number sent to every vessel fitting out for sea. The plan has worked admirably, and the seamen gunners promise to become a most useful and efficient class of men. The Atlanta has eleven of them, three being detailed for duty in the dynamo room. Whenever the plant is in operation they stand regular watch in the dynamo room, their duties being to look after the dynamo and its engine, and record hourly the revolutions of each, the steam pressure, and the temperature; and also record the time that any lamps burn out or are broken. At noon the record for the previous twenty-four hours is handed to the officer in charge, and it is entered in the "dynamo room log-book." As soon as the plant is shut down each circuit is tested (by means of a small magneto machine), and if leaks are discovered on any circuit they are at once located and the fault repaired, a note being made of it in the log. A complete record of the working of the plant is thus obtained. During the day the men clean the lamps and fixtures, make any repairs that may be needed, and clean the engine and dynamo carefully. At the end of each quarter a report is sent in to the Navy Department giving a record of the lives of the lamps, the number burnt out and broken, and any information of interest in regard to the working of the plant. In recording the lifetime of lamps, only such lamps can be taken as burn all the time, or are turned on and off at certain known times, and they number less than half the total number of lights. On board the Atlanta there are 273 lamps in place, and of these the lives of 99 are recorded. To guard against a lamp being taken from one holder and put in another by the men, the following plan has been adopted: Each holder is given a number, which is recorded. Whenever a lamp is put in this holder its number is marked in ink on a piece of paper pasted on the lamp, the number of the lamp and the date both being recorded. If the life of the lamp is recorded it is only necessary, when it burns out, to refer to its number, ascertain the date the lamp was put in place, and then calculate how many hours it has been burning. To facilitate this the number of hours the plant has been in operation during the preceding twenty-four hours is recorded in the log each day, and added up at the end of each month and quarter. Whenever a lamp burns out, its life is figured up (if possible) at once and entered in the log. By so doing the work is kept up to date, and a great deal of work is saved when the end of the quarter comes. In locating faults, the circuit in question is gone over carefully, the moldings examined to see if they have been hit or broken, and all fixtures and cut-out boxes examined to see if salt water has worked its way in. With a little practice a man soon becomes very expert in locating leaks or breaks and in repairing them. It has frequently happened on board the Atlanta that a lamp will not burn, and the cause has been found to be the burning out of the small connecting wires in the sockets of the fixtures. It is due probably to these wires being too small, and they have been replaced in every case with a slightly larger wire, no further trouble being experienced. Some of the safety-strip boxes on the fire-room circuits are placed, unavoidably, either directly over or near the boilers. When steam was raised on these boilers it was found that several of the lights in the fire-rooms would not burn. Upon examination the safety strips were found burnt out, and the supposition is that the intense heat over the boilers, added to the heat generated by the current, was sufficient to fuse the strips, and the latter have accordingly been replaced with small lengths of wire of the same size as the circuit wires. This experience would seem to show that if the safety strips are to be used at all on these circuits the boxes inclosing them should be lagged with some non-conductors of heat.

The Atlanta's plant was put into operation on September 4, 1886, and since that time it has been running every night. Up to the last of March it had been in operation 3,542 hours, or an average of 17 hours daily. The engine, dynamo, and the whole system are in excellent condition, and it seems difficult now to imagine how it would be possible to do without the electric lights. They certainly add very much to the comfort and health of everybody, and they also add to the efficiency of the ship as a fighting machine. The ship has now been in commission over nine months, and that time has sufficed to make everybody connected with the plant thoroughly familiar with it. Some defects, already mentioned, have been discovered and remedied, defects which only practical experience could develop, but which can be avoided in future vessels. The Atlanta's plant as a whole, however, is a great success, and its many good points can well afford to be copied hereafter.

In conclusion, the following may be summarized as the principal requisites of an efficient plant:

(1) The plant to consist of two or more dynamos, with their engines, each being an exact duplicate of the other, so that their parts are interchangeable.

(2) The plant to be located below the water-line, or at least below the protective deck, if the ship has one.

(3) The insulation of all wires to be the best rubber insulation that can be obtained, and the wires to have a lead covering.

(4) The insulation of the whole system to be complete, and all junction boxes, switches, cut-out boxes, fixtures, &c., to be absolutely water-tight, so that a hose can be played on them if necessary and no water get in.

If these points are carefully attended to the plant will reflect credit upon every one connected with it and will never fail when called upon in time of need.

SEARCH-LIGHT PLANT.—ATLANTA.

The search-light plant of the Atlanta consists of two 60-centimetre Mangin projectors, with the lamps, mirror lenses, &c., complete; two dynamos for running the same, and a 3-cylinder Brotherhood engine for operating the dynamos. The projectors and all the attachments are of French make, being manufactured by Sautter, Lemonnier & Cie., of Paris, and were sent to this country ready for mounting on board ship. They are mounted on top of the port forward, and starboard after Hotchkiss-gun towers, and each has a sweep over about 200° of the horizon. The projectors are mounted on a pivoted saddle, and swung on trunnions, so that a movement of rotation about two axes at right angles is obtained. The carbon-holders are not vertical, but set at an angle of about 45°, so that the light from the crater in the upper carbon is thrown directly on to the silvered lens at the back of the projector. The carbons are fed together by a worm wheel underneath the lamp. One man can handle the projector and regulate the carbons with ease, but, owing to the blinding effect of the light, it is necessary to have a man stationed a few feet from it, in order to direct the movement of the projector and discover objects which it may illuminate. The dynamos, with the engine, are situated in the dynamo room on the berth deck, and permanent wires lead from them to the search lights forward and aft. The engine is coupled direct to the dynamos, and is between them, on the same bed-plate. The dynamos are what are known as the D. E. "series-wound" Gramme machines, having a switch-board on the front of each, and a pole-changer, as shown in Figure 5, which also shows the connections of the machines to the pole-changer and the direction of the current. With the switches of the switch-boards in the position shown, the circuit of each machine is broken, and is only made when the switches are thrown to the right, in the direction of the arrows. With the handle on the barrel of the pole-changer *up*, as shown, the current from the positive binding post on each switch-board goes to posts 4 and 5 of the pole-changer, thence to posts 1 and 2 by the metal strips on the base-board, and so out to the lamps, returning to posts 7 and 8, 9 and 10, and finally back to the switch-boards and machines. If, however, the handle of the pole-changer be turned *down* 45° the strips connected to posts 4 and 5 are connected, as are also posts 3 and 6.

The positive poles of the two machines are thus connected, also the positive brushes (by means of the strips attached to posts 3 and 6), and the machines are now coupled together in "arc," and if they are thrown on to *one* light, its power is nearly doubled, or at least very much increased. The following table (furnished by the manufacturers) gives the electrical dimensions of the machines and lights: (1) when one machine is on one light, and (2) when both machines are on one light:

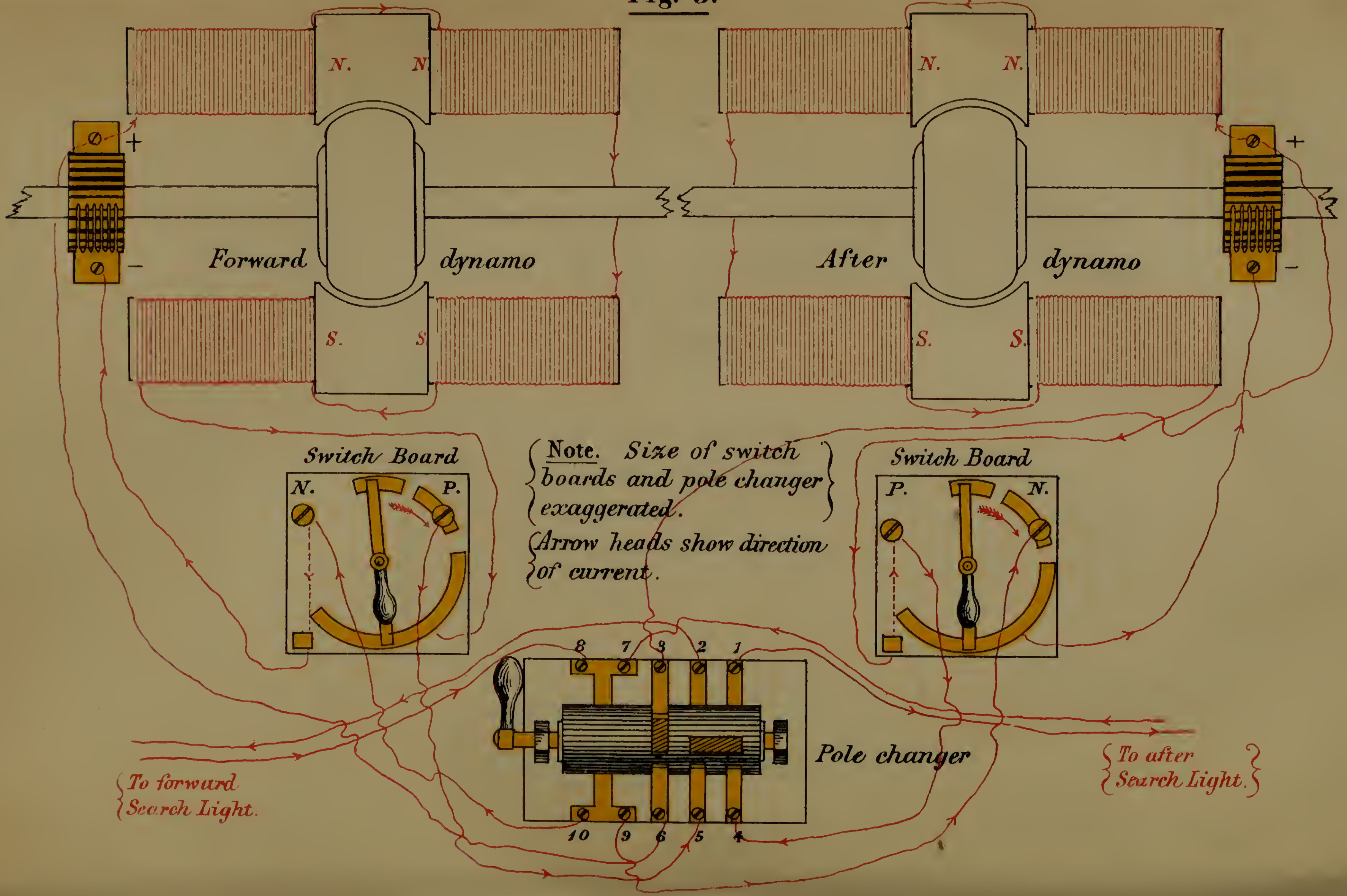
	One machine, 1 light.	Two machines, 1 light.
Internal resistance ....ohms..	0.825	0.412
External resistance (conductors *plus* resistance of arc)........do...	0.965	0.869
Electromotive force developed........volts..	86	89
Current developed........ampères..	48	70
Candle-power of lights........	23,750	46,700
Horse-power necessary........	5.25	10.5
Revolutions of machines........	675	675

The search lights of the Atlanta have been tried several times with one machine on each light, and with both machines in "arc" on one light, and they have worked very satisfactorily. A man soon becomes expert in regulating the arc of the light so as to let the crater on the upper carbon throw the greatest amount of light on the lens, and there is little about the light or the dynamos to get out of order.

The Atlanta's steam-launch is also provided with a search light, dynamo, and engine, precisely similar to the ship's lights, but smaller. The light is a 9,600 candle-power one, and is mounted on the forecastle of the launch, the engine and dynamos being placed in the after cockpit. It was thought at first that the Brotherhood engine, making 1,600 revolutions per minute, would require so much steam to run it as to seriously diminish the speed of the launch; but on trial it was found that the steam pressure (Herreshoff boiler) could easily be kept above 100 pounds per gauge by using the jet draft into the smoke-pipe more frequently, and the speed of the boat was not reduced more than a knot at most, probably not as much. If the launch were required as a patrol boat or picket to detect the approach of an enemy's torpedo boats at night, the search light would be very useful.

Experiments were tried some time ago on board the Atlanta with the Gramme dynamos, to see if they could be made to run the incandescent lamps. One machine, and the two machines in "arc," were taken direct to the main switch-board (of the incandescent lamps) in the dynamo-room and several circuits thrown on, the result being that there was not even a reddening of the carbon filaments. Recently, however, at the suggestion of the Inspector of electric lighting of ships, the two machines were coupled together in series and tried on six circuits, a total of about one hundred and fifty lamps. The lamps were found to burn very well apparently, and at about their normal pressure (110 volts), but there was no voltmetre on board to verify this. After three-quarters of an hour's running the field-magnet coils of both machines were uncomfortably warm, and they were stopped. More recent experiments show that about fifty lamps can be run with the two machines in arc, for four or five hours, if necessary.

Fig. 5.



Note. Size of switch boards and pole changer exaggerated.

Arrow heads show direction of current.

III.

SYSTEMS OF FORCED DRAFT.

Compiled and arranged by Assistant Engineer R. S. GRIFFIN, U. S. N.

CLOSED STOKEHOLDS.

By RICHARD SENNETT, Esq., R. N., *Engineer-in-Chief to the British Admiralty.*

[Read at the twenty-seventh session of the Institution of Naval Architects, April 15, 1886.]

The application of forced draft to the furnaces of marine boilers is a subject of considerable interest at the present time, and has, in one form or other, been brought before the notice of this Institution at each of our last three annual meetings.

The only system that has yet had any extended practical trial is that of closed stokeholds worked under air pressure, which was described by Mr. R. J. Butler at the meeting in 1883, when he gave particulars of the application of the system to H. M. S. Conqueror and Satellite, and the results of the trials made to ascertain its efficiency. These trials, though incomplete in some respects, as explained by Mr. Butler, were of great value for guidance in future designs, and showed clearly that the generative powers of the boilers could, by a simple and comparatively inexpensive method, be very materially increased.

Since that time all the ships built for the Royal Navy, and many other vessels, have been fitted with this system, and the results obtained have been most satisfactory. My object in writing this paper has been to lay before the members of this Institution the results obtained during some of the more recent trials. As to the value of these results, and the promise they show of future progress, you will be able to form your own judgment.

Detailed particulars of the machinery of the ships, and the results of their trials, are given in the tables attached, and it is only proposed in the body of the paper to deal with the leading features of the subject.

All the trials were made in accordance with the usual Admiralty practice. The indicator diagrams were taken at regular half-hourly intervals, and the revolutions were taken, at the end of each half-hour, from the indications of mechanical counters worked off the engines, the mean of the half-hourly totals being used for the calculation of the I. H. P. The results may, therefore, be safely relied on as the average performances during the trial.

It will be unnecessary to occupy time in describing the method of application of the system of closed stokeholds to the ships in question, as it is practically the same as that explained by Mr. Butler in his paper, simplified and improved in some details as experience has been gained. [It consists essentially in fitting hinged doors over the openings above the boilers, and light sheet-iron bulkheads around their front ends, so as to have the smallest possible space to keep under pressure. Air is drawn by fans either from the usual fire-room ventilators, or from special air shafts, and forced into this space, all openings to which are provided with air locks.]

We will first take the case of the twin-screw armor-clad barbette ship Rodney. She is fitted with twelve boilers, arranged in four separate and independent stokeholds, the working steam pressure being 90 pounds per square inch. The arrangement of the fans and screens in each stokehold, for forced draft working, is shown in Figs. 1 and 2, Plate I. There are two fans, 5 feet in diameter, for each stokehold, one at either end, fixed on the débris deck that forms the air-tight ceiling of the stokehold. The engines of the Rodney are vertical 3-cylinder compound, each set having one high and two low pressure cylinders, the ratio of the volume of the high to that of the two low pressure cylinders being 1 to 4.05. The proportions of the boilers and engines are such that with natural draft alone an I. H. P. of from 7,500 to 8,000 would be developed.

A four hours' trial with forced draft was made on the 13th June, 1885, all twelve boilers being used. The mean I. H. P. developed was 11,158, with an average air pressure in the stokeholds equal to 1.4 inches of water. This gives a mean of 14.75 I. H. P. per square foot of fire-grate, and 18.5 I. H. P. per ton of boiler (including water, uptakes, fittings, &c.).

It was seen during this trial that the boiler power was in excess of the capacity of the engines to utilize the steam generated, and a subsequent trial was, therefore, made on the 16th June, 1885, with nine boilers only in use. The air pressure during this trial was gradually raised from 1½ to 2 inches of water, and the average I. H. P. developed was 9,544, which is equal to 16.83 I. H. P. per square foot of fire-grate. During the last hour of this trial, when the air pressure was kept equal to 2 inches of water, the mean I. H. P. developed was 9,760, or 17.2 I. H. P. per square foot of fire-grate. The boilers generated an ample quantity of steam, the safety valves blowing freely throughout the trial.

The forced draft trial of the Howe, a sister ship to the Rodney, was made on the 14th January, 1886; the maximum I. H. P. developed was

12,118, and the average for the four hours 11,725, or at the rate of 15.5 I. H. P. per square foot of fire-grate.

We will next take the case of the fast twin-screw cruiser Mersey, whose official forced draft steam-trial was made off the Nore on the 24th September, 1885. The Mersey is fitted with six boilers of the low cylindrical marine type, arranged in two stokeholds; and with natural draft alone would be equal to about 4,000 I. H. P. The working steam pressure is 110 pounds per square inch. The general features of the stokehold arrangements are shown in Figs. 3 and 4, Plate II. In the Mersey the supply to the fans is through air trunks carried direct to the upper deck. Two 5-feet fans are fitted for each stokehold. The engines of the Mersey are horizontal compound, each set having one high and one low pressure cylinder, the ratio of the high to the low being 1 to 2.84. The average I. H. P. developed during the trial was 6,628, with an air pressure in the stokeholds equal to 2 inches of water. This represents 16.61 I. H. P. per square foot of fire-grate, and 21.7 I. H. P. per ton of boiler (including water, uptakes, fittings, &c). This is the highest result that has yet been obtained with ordinary marine boilers.

The results of trial of the torpedo cruiser Scout were practically the same as those of the Mersey. The machinery and boilers are of similar type but smaller. The Scout has four boilers, two in each stokehold, and the working pressure is 120 pounds per square inch. The average I. H. P. developed on the forced draft trial made at Spithead, on the 23d September, 1885, was 3,370, which is equal to 16.28 I. H. P. per square foot of fire-grate, and 19.3 I. H. P. per ton of boiler.

In the development of this system of forced draft, care has been exercised to insure that each step taken was safe, and justified by previous experience, in order to avoid the risk of failure from taking a too sanguine view of the possibilities of the system. As a matter of fact, in no case yet, on a full power trial, have the boilers been worked to the full extent of their capabilities, and the reserve of power in the fans has kept the steam supply always fully under command.

In some trials made by using a portion only of the boilers, so that all the steam generated could be readily utilized by the engines, the results obtained have been higher than those quoted from the full-power trials. Several trials of the machinery of the sloop Caroline were made in basin at Sheerness in March, 1885, with only one-half of the boilers in use. The results of one of these trials, of six hours' duration, are given in table attached, from which it will be seen that, with an air pressure equal to not more than $1\frac{1}{2}$ inches of water, 18 I. H. P. was developed per square foot of fire-grate. The Caroline is a sister ship to the Satellite, referred to in Mr. Butler's paper, and the particulars and arrangements of the machinery and boilers are practically the same as in that ship.

To enable the comparative value of these results to be properly appreciated, I have shown in the following table particulars of the performances of similar ships, some with ordinary open stokeholds, and others with closed stokeholds and forced draft:

Ship.	Date.	Load on safety valves.	I. H. P.	Weight of boilers.	Area of fire-grate.	I. H. P. per square foot of fire-grate.	I. H. P. per ton of boiler.
Open stokeholds.		*Pounds.*		*Tons.*			
Inflexible	1878	60	8, 483	756	829	10.21	11.22
Colossus	1883	64	7, 492	594	645	11.62	12.61
Phaeton	1884	90	5, 588	462	546	10.23	12.1
Forced draft.							
Howe	1885	90	11, 725	632	756	15.54	18.5
Rodney (9 boilers)	1885	90	9, 544	474	567	16.83	20.1
Mersey	1885	110	6, 628	306	399	16.61	21.7
Scout	1885	120	3, 370	174	207	16.28	19.3
Trafalgar (estimated)	......	135	12, 000	514	609	20.00	23.3

NOTE.—The weight of boiler given includes weight of water, funnel, uptakes, fittings, spare gear &c.

By referring to the seventh column of this table, it will be seen that whilst in the ships with natural draft only, about 10¼ I. H. P. was developed per square foot of fire-grate, between 16 and 17 I. H. P. was obtained with moderate forced draft, the boilers being practically the same in the two cases. The steam blast was used throughout the trial of Colossus.

The grate area can only be used as a fair basis of comparison for boilers similar in design and construction. I have, therefore, in the last column, given the I. H. P. developed per ton weight of boiler, which is the more important feature, so far as the naval architect is concerned, and we see from this column that the effect of the application of forced draft has been to increase the power obtained from a given weight of boilers in the proportion roughly of 20 to 12, the engines and boilers being of practically the same description in both cases.

In the Nile and Trafalgar, and other war ships now building, triple expansion engines will be fitted, worked with steam of 130 to 140 pounds pressure per square inch. From the experience we have now gained respecting the steam generating powers of boilers in closed stokeholds kept under moderate air pressure, and the well-known economical employment of steam in triple expansion engines, we are satisfied that on the full power trials of these vessels, at least 20 I. H. P. per square foot of grate, and between 23 and 24 I. H. P. per ton of boiler will be realized, and this condition has been readily accepted by the engine contractors, who have had experience of the working of the system.

As before stated these results are obtained without any undue forcing of the boilers, the maximum limit of the air pressure allowed on the Admiralty trials being equal to two inches of water, or about $\frac{1}{13}$ of a pound per square inch, and the boilers have in no way suffered from the work. It is probable that, as further experience in the working of the system is gained, the air pressure in the stokeholds may be safely maintained at a somewhat higher point than two inches of water, with a corresponding increase in the steaming powers of the boilers.

The many advantages as regards the power and speed of steamships that are gained by this great reduction in the weight and space required for the boilers are too obvious to require enumeration, and it is perhaps not too much to say that the very high speeds that have been recently obtained by several cruisers of moderate dimensions would have been impracticable without the application of forced draft.

There are several subsidiary advantages resulting from this system of working, which should be briefly mentioned.

The ventilating pipes with large reversible cowl-heads above the upper deck, necessary for natural ventilation, but which are generally objectionable, and frequently interfere with the working of the ship or guns, can be to a great extent, if not altogether, dispensed with and the openings in the deck reduced to the minimum required for supply of air to the fans, and for access to the engine and boiler rooms, &c. In the larger ships, as shown in Figs. 1 and 2, the fans are simply fixed on the débris deck above the boilers, and the air finds its way to them from the ordinary ship's hatchways, no special ventilating trunks being necessary.

It has always been requisite in large war ships, in consequence of the difficulty of arranging suitable openings in the upper deck and carrying air trunks from them to the stokeholds for natural ventilation, to fit fans to blow air into the stokeholds, and the system of closing in the stokeholds, now adopted, is only the completion of the original plan, in order to increase the supply, and to insure that the air blown into the stokeholds shall pass through the fires.

When blowing fans are fitted to supply the air for the fires in closed stokeholds, the power of the ship is practically independent of the force and direction of the wind, which is a matter of no small importance, especially when steaming in the tropics. By the use of the fans the fires may be kept working uniformly, and the exhausting work of raking and stirring the fires, so frequently required during calm weather with open, natural draft stokeholds, is avoided, and the power developed can be easily and quickly regulated by the speed at which the fans are driven.

Stokeholds, worked under air pressure, are also necessarily kept cool and well ventilated under all conditions, which is beneficial to the stokers, and is a point that does not appertain to any other system of forced draft. When the system was first adopted it was suggested that the men might have some reluctance to work in closed stokeholds. This, however, has not proved to be the case, and the men have, from the first, worked as confidently and cheerfully as in ordinary stokeholds. The only effect that the closing of the stokeholds has had upon the men has been to enable them to do their work in more comfort, in consequence of the better ventilation.

It is unnecessary to occupy time in enumerating other minor points of advantage possessed by the closed stokehold system, which will occur readily to all who have had experience in its working.

There is, however, one important feature about which a wrong impression appears to exist in some quarters. It is assumed that the system is necessarily uneconomical, so far as the consumption of coal is concerned. This, however, is not the case; the closed stokehold system, in common with other good forced draft systems, tends to promote economy of fuel, in consequence of the better supply of air and the higher temperatures at which the fires are worked. It is true that on some full power forced draft trials of ships in the Royal Navy the consumption of coal per I. H. P. has been somewhat in excess of the expenditure required for natural draft alone. This, however, is not due to the method in which the coal is burnt, but simply results from the waste heat that passes up the funnel in consequence of the comparatively small proportion of heating surface to the coal burnt.

Engines of war ships are only occasionally required to work at their maximum power, and it is considered preferable to accept the slight loss that occurs on these occasions in consequence of the waste heat in the escaping gases, rather than to permanently increase the weight of, and space occupied by, the boilers, by providing heating surface fully equivalent to the maximum rate of combustion of coal in the furnaces. For all ordinary cruising the closed stokehold system is most economical; the furnaces are supplied with the proper quantity of air they require, and any sudden increase of power necessary is readily obtained by simply driving the fans faster.

So far as war ships are concerned, I have no doubt whatever that, at present, it is the only system that commends itself for general application, and I look forward with confidence to considerable extension in its application and usefulness. It has been adopted not only for ships for the Royal Navy, but also very largely by the designers of war ships for foreign navies.

How far it is applicable to mercantile steamers making long sea voyages it is, perhaps, scarcely within my province to say. It has been fitted successfully by Messrs. Laird to the Dublin and Holyhead Royal Mail packets, and I have no doubt that very great advantage would result from its adoption for other steamers employed on similar service.

There is also every reason to believe that the system of closing the stokeholds and fitting blowing fans might be applied to ocean steamers generally with much advantage. The closing of the stokehold is quite independent of forcing the draft. The fans could be made to supply the furnaces with air, without producing any appreciable pressure in the stokeholds; or, if pressure be used, the area of the heating surface of the boilers could be designed to suit the increased rate of combustion.

In large ocean steamers the necessary air trunks and casings, carried above the upper deck, to supply the air required for the stokeholds, occupy valuable space, and the power and speed of the ship, especially

PLATE I.

H. M. S. "RODNEY."

FIG. 1.

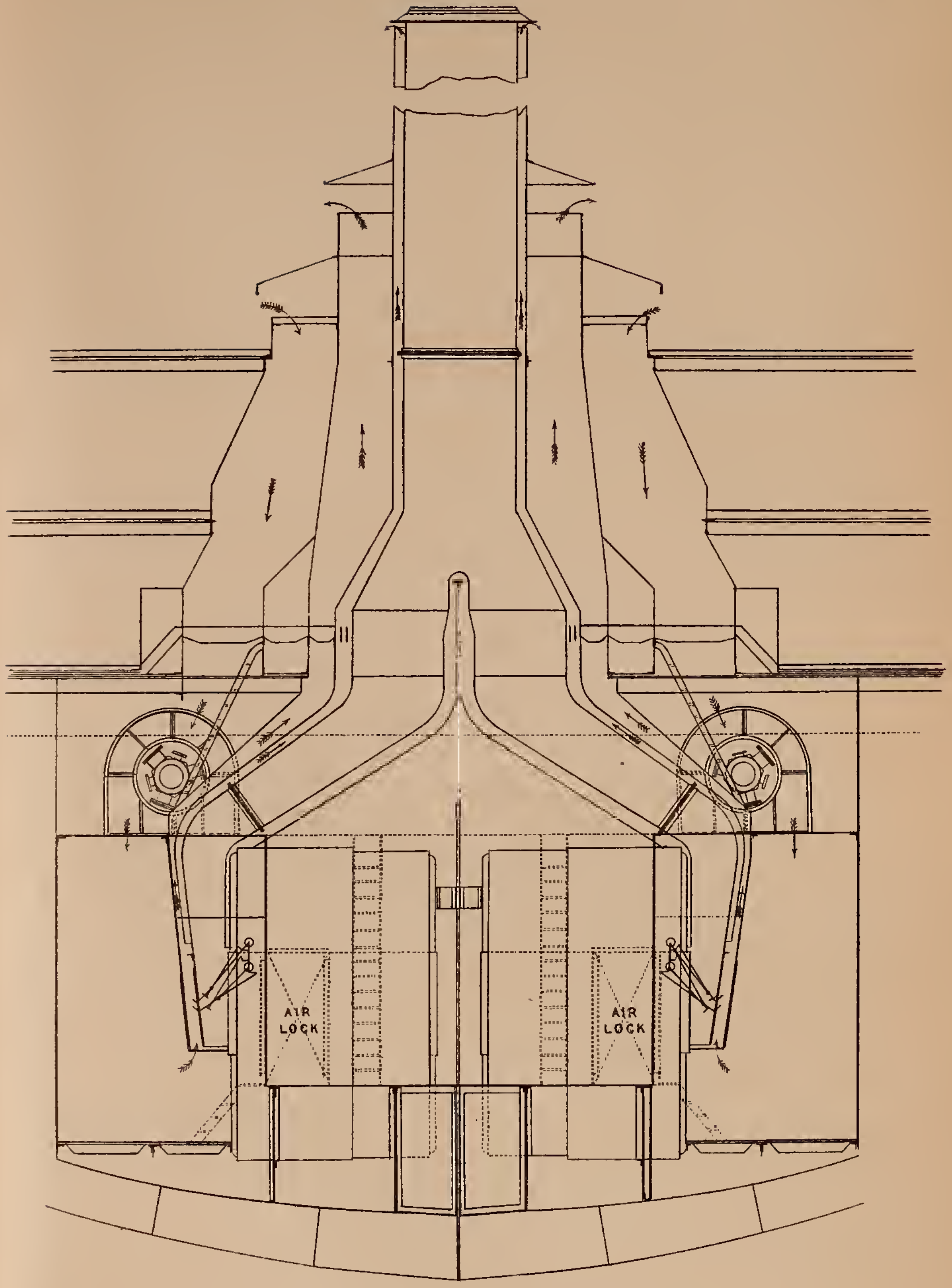
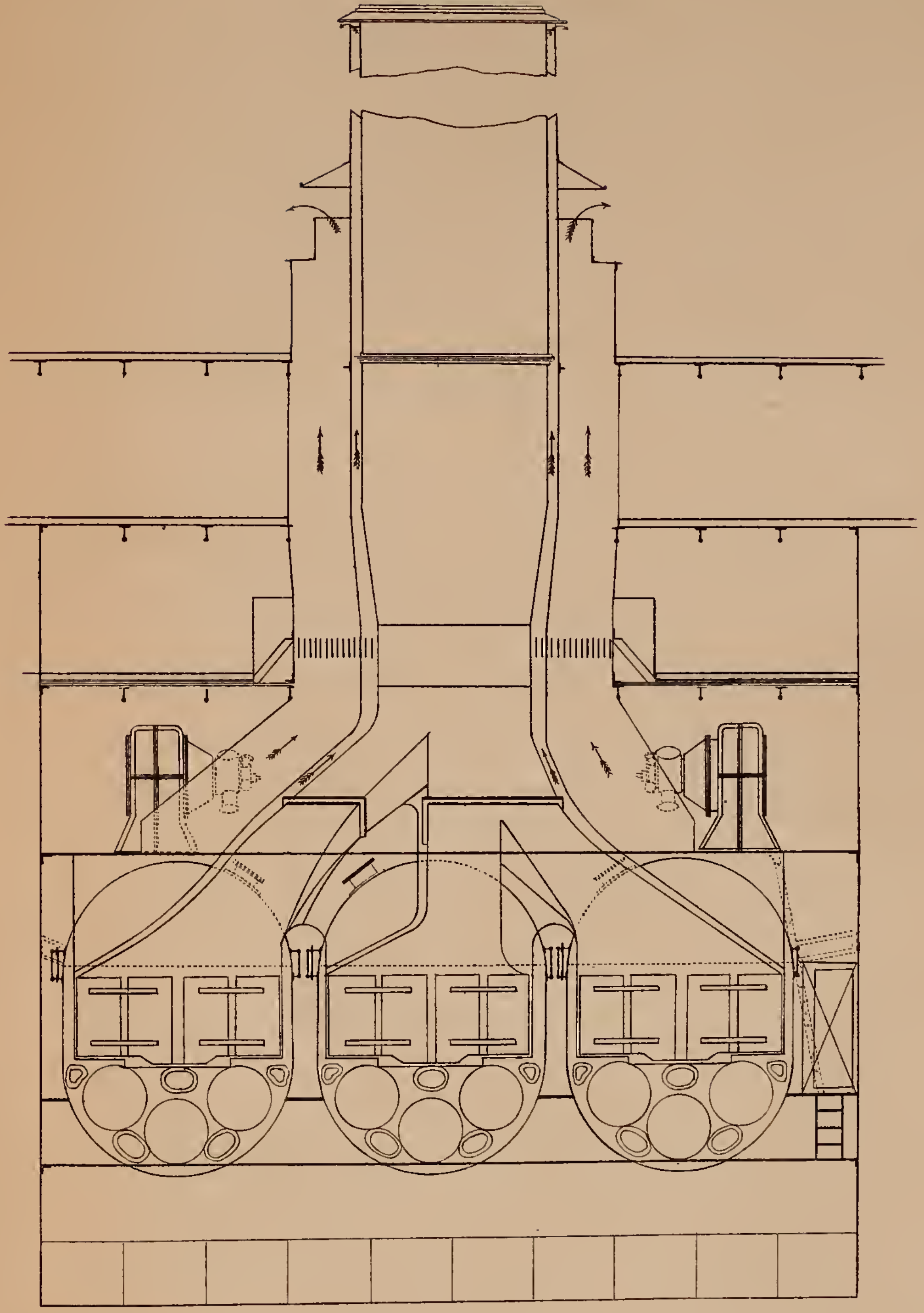


FIG. 2.



SCALE OF FEET

5 4 3 2 1 0 5 10 15 20 25 30 35

H. M. S. "MERSEY"

PLATE II.

Fig. 4.

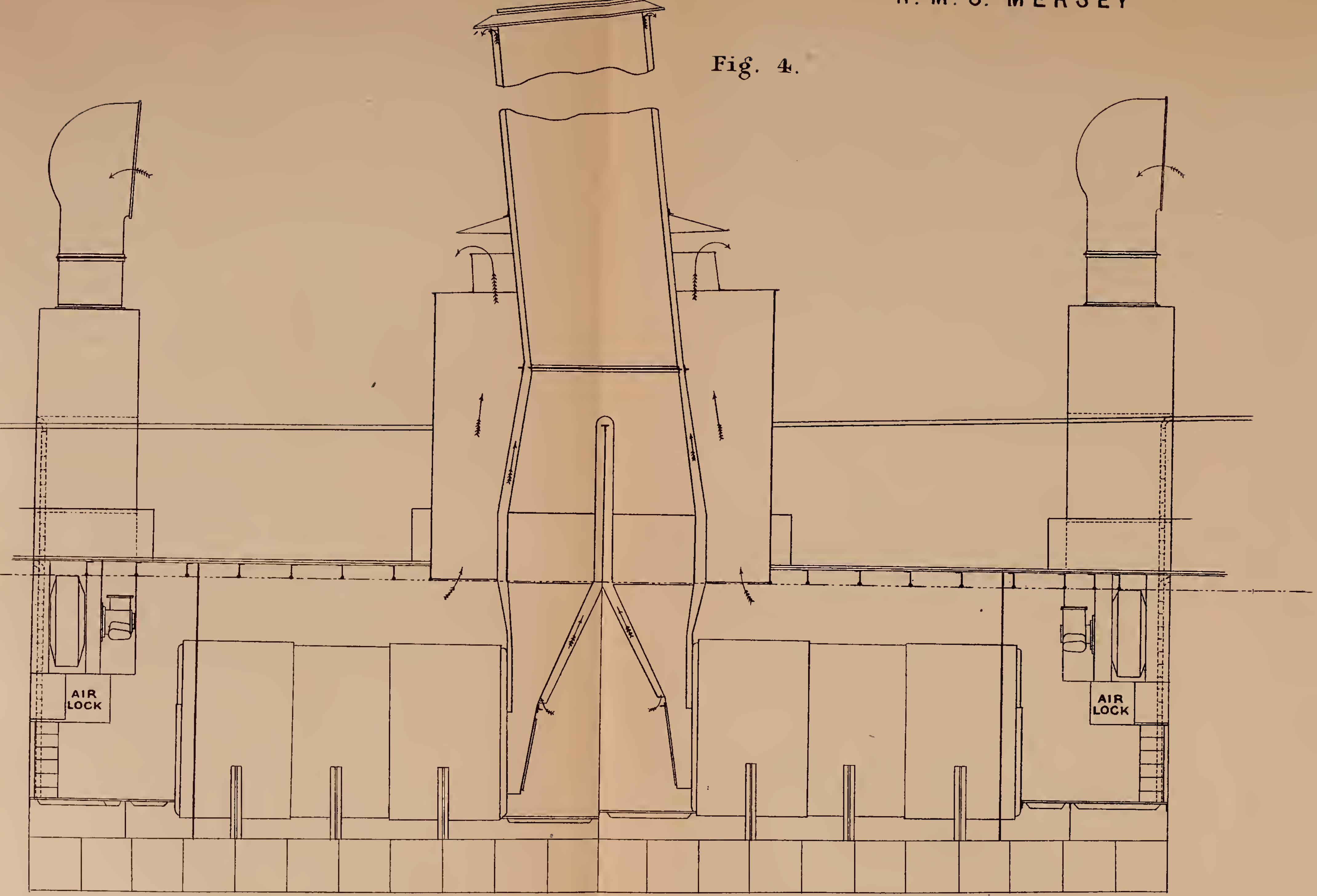
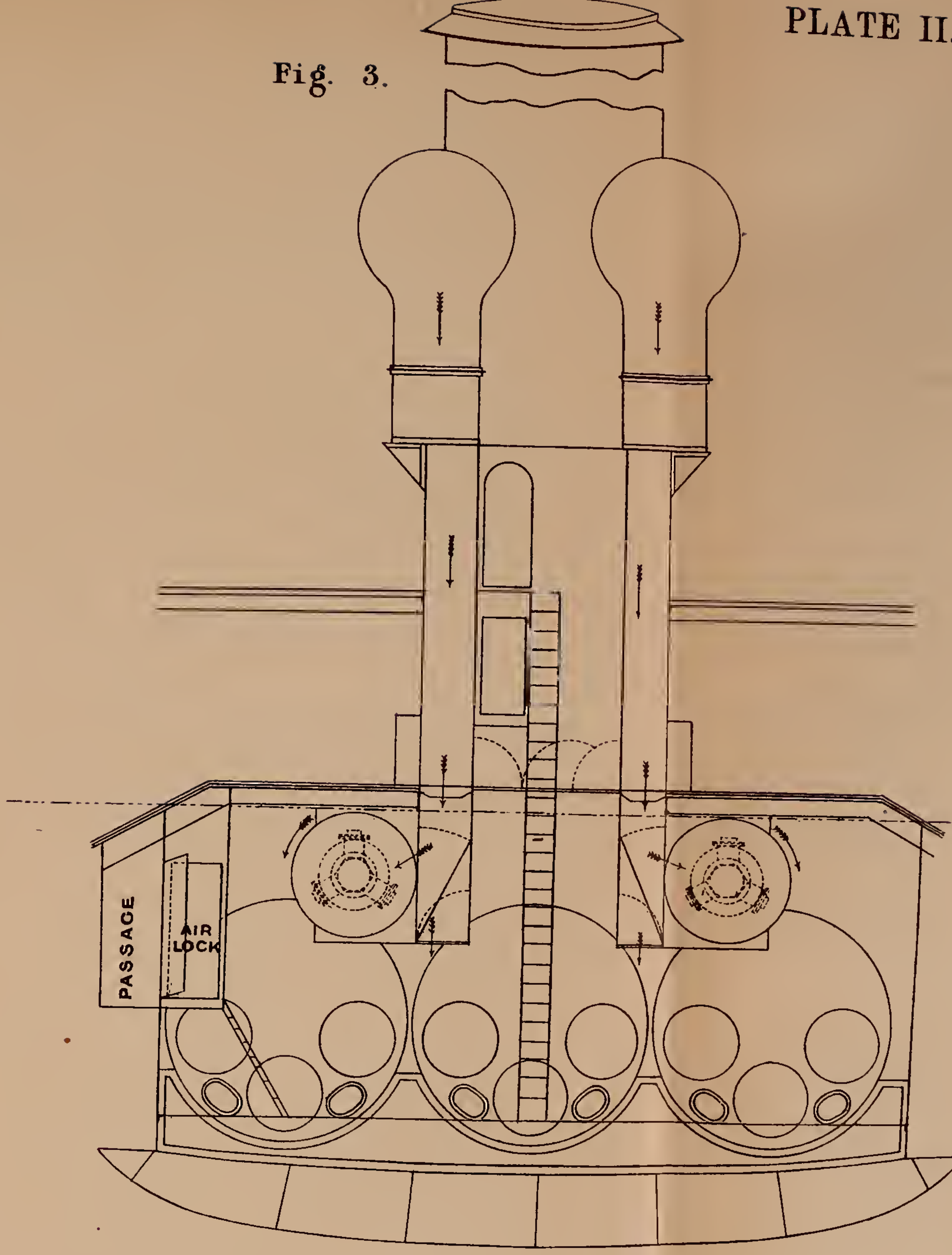
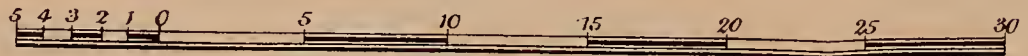


Fig. 3.



SCALE OF FEET.



on some services, must depend largely on the force and direction of the wind. If the stokeholds were closed in, and the air to them supplied by fans placed on the deck in a somewhat similar manner to that adopted in war ships, the state of the weather would be of small importance so far as the steam-generating powers of the boilers were concerned, and the power and speed of the ship could be maintained under all conditions. This would doubtless tend to reduction in the space and weight required for the boilers, and lead to improvements in many other ways. I would not presume to dogmatize on this point, but merely throw out the suggestion for the consideration of those members who are more intimately concerned with the design of machinery for the mercantile marine.

TABLE I.—*Particulars of machinery.*

Particulars.	Inflexible.			Colossus.	
Description of engines	3 cylinder vertical compound.			3 cyl. vert. comp.	
Diameters of cylinders:					
High pressure	2 of 70″			2 of 58″	
Low pressure	4 of 90″			4 of 74″	
Length of stroke	4′ 0″			3′ 3″	
Propeller:					
Description	2 bladed			4 bladed	
Diameter	20′ 2½″			17′ 8½″	
Pitch	23′ 0½″			18′ 7¼″	
Boilers:					
Number	12			10	
		Four each of		Eight	Two
Description	Oval 3 furnace	Oval 2 furnace	Oval double ended 4 furnace	Oval 3 furnace	Oval 2 furnace
Transverse dimensions	13′ 7″ × 15′ 6″	11′ 1″ × 13′ 4″	9′ 4″ × 14′ 3″	12′ 9″ × 15′ 3″	7′ 10″ × 14′ 0″
Length	9′ 0″	9′ 0″	17′ 0″	9′ 9″	9′ 9″
Load on safety-valves, pounds	60			64	
Furnaces:					
Number	36			28	
	Twelve of	Eight of	Sixteen of	Tw'ty-four of	Four of
Diameter	3′ 6″	3′ 3″	3′ 6″	3′ 5″	2′ 10″
Length	6′ 0″	6′ 0″	6′ 6″	6′ 9″	6′ 9″
Grate area, sq. ft	829			645	
Heating surface of boilers, in square feet:					
Tubes	18,654			14,747	
Total	22,288			17,507	
Area through tubes, sq. ft	158			117	
Funnels:					
Number	2			1	
Size	Oval 10′ 0″ × 8′ 0″			Oval 12′ 0″ × 8′ 0″	
Height above fire bars	70′ 3″			80′	
Ratios to grate area:					
Tube heating surface	22.5			22.8	
Area through tubes	.190			.181	
Area of funnels	.160			.128	

TALE I.—*Particulars of machinery*—Continued.

Particulars.	Phaeton.	Mersey	Scout.	Rodney and Howe.	Trafalgar proposed.
Description of engines	Horiz. comp.	Horiz. comp.	Horiz. comp.	3 cyl. vert. comp.	Vert. triple expansion.
Diameters of cylinders:					
High pressure	2 of 42″	2 of 38″	2 of 26″	2 of 52″	2 of 43″ 2 intermed. of 62″
Low pressure	2 of 78″	2 of 64″	2 of 46″	4 of 74″	2 of 96″
Length of stroke	4′ 0″	3′ 3″	2′ 6″	3′ 9″	4′ 3″
Propeller:					
Description	4 bladed	3 bladed	3 bladed	4 bladed	Undecided.
Diameter	14′ 0½″	13′ 0″	10′ 6″	15′ 6″	
Pitch	20′ 1¾″	18′ 5⅞″	12′ 6″	19′ 6″	
Boilers:					
Number	8	6	4	12	6
Description	Cylind. high 3 furnace	Low cylind. 3 furnace	Low cylind. 3 furnace	Oval 3 furnace	High cylind. 4 furnace
Transverse dimensions	13′ 5″ dia.	10′ 0″ dia.	9′ 3″ dia.	11′ 0″ × 15′ 0″	16′ 2″ dia.
Length	9′ 8″	18′ 9″	17′ 10″	9′ 8″	10′ 3″
Load on safety-valves, pounds.	90	110	120	90	135
Furnaces:					
Number	24	18	12	36	24
Diameter	18 of 3′ 3″ 6 of 3′ 0″	3′ 2″	2′ 10″	3′ 0″	3′ 7½′
Length	7′ 0″	7′ 0″	6′ 0″	7′ 0″	7′ 4″
Grate area, sq. ft	546	399	207	756	609
Heating surface of boilers, in square feet:					
Tubes	12, 456	10, 367	5, 500	17, 174	17, 040
Total	14, 562	11, 700	6, 170	20, 294	19, 390
Area through tubes, sq. ft	87. 5	61	32	102	96
Funnels:					
Number	2	1	1	2	2
Size	8′ 0″ dia.	7′ 2″ dia.	6′ 6″ × 4′ 9″	9′ 0″ × 5′ 6″	7′ 0″ dia.
Height above fire bars	61′ 8″	52′ 6″	55′ 0″	75′ 0″	65′ 0″
Ratios to grate area:					
Tube heating surface	23. 3	25. 9	26. 5	22. 7	28
Area through tubes	. 160	. 152	. 154	. 134	. 158
Area of funnels	. 183	. 100	. 125	. 114	. 126
Forced draft fans:					
Number	....	4	4	8	6
Diameter	....	5′ 0″	3′ 6″	5′ 0″	5′ 6″

TABLE II.—*Abstract of steam-trials.*

	Open stokeholds.		
	Inflexible.*	Colossus.†	Phaeton.‡
Date of trial	Nov. 14, 1878.	Jan. 10, 1884.	Feb. 12, 1884.
Duration of trial, in hours	6	5	5
Number of boilers used	12	10	8
Mean steam pressure in boilers, pounds	61.06	61.52	85.35
Mean pressure in cylinders in pounds, per square inch:			
High pressure	29.55	40.66	43.56
Low pressure	9.833	12.09	11.43
Mean revolutions per minute	73.26	89.96	100.26
Mean speed of piston, in feet, per minute	586	585	802
Indicated horse-power	8,483	7,492	5,588
Area of fire-grate used, in square feet	829	645	546
I. H. P. per square foot of fire-grate	10.21	11.62	10.23
Heating surface per I. H. P., in square feet:			
Tubes	2.20	1.97	2.23
Total	2.63	2.33	2.61
Coal used per I. H. P. per hour, in pounds	2.06	2.55	2.39
Coal used per hour, in tons	7.80	8.53	5.96

	Forced draft.					
	Mersey.	Scout.	Rodney.		Howe.	Caroline.
Date of trial	Sept. 24, 1885.	Sept. 23, 1885.	June 13, 1885.	June 16, 1885.	Jan. 14, 1886.	Mar. 4, 1885.
Duration of trial, in hours	3	4	4	3	4	6
Number of boilers used	6	4	12	9	12	2
Mean steam pressure in boilers, pounds.	107.8	113.09	93.06	92.74	89.21	84.52
Mean air pressure in boiler rooms, in ins. of water	2.02	1.52	1.4	1.89	2.05	1.5
Mean pressure in cylinders, in pounds, per square inch:						
High pressure	56.53	61.42	59.92	49.73	59.51	43.9
Low pressure	22.82	24.31	12.8	12.1	13.43	12.79
Mean revolutions per minute	122.34	152.33	103.42	100.13	106.63	77.8
Mean speed of piston, in feet, per minute.	795	762	776	751	800	389
Indicated horse-power	6,628	3,370	11,158	9,544	11,725	983
Area of fire-grate used, in square feet	399	207	756	567	756	54.5
I. H. P. per square foot of fire-grate	16.61	16.28	14.75	16.83	15.51	18.02
Heating surface per I. H. P., in square feet:						
Tubes	1.56	1.63	1.54	1.35	1.46	1.24
Total	1.77	1.83	1.82	1.6	1.73	1.43
Coal used per I. H. P. per hour, in pounds	2.48	2.6	2.2	....	2.16	2.54
Coal used per hour, in tons	7.33	3.92	11	....	11.30	1.11

* Blast used last half hour only. † Blast used throughout the trial. ‡ Natural draft only.

NOTE.—The I. H. P. recorded is that developed by the main engines only, and does not include the I. H. P. expended in working the feed and circulating pumps, blowing fans, and other auxiliary machinery.

ON FORCED COMBUSTION IN FURNACES OF STEAM BOILERS.

By JAMES HOWDEN, Esq.

[Read at the twenty-seventh session of the Institution of Naval Architects, April 15, 1886.]

In a paper I had the honor of reading at our annual meeting of 1884, "On combustion of fuel in furnaces of steam boilers by natural draft and by supply of air under pressure," I directed attention to the following facts:

1. That the great reduction in the consumption of fuel, effected during the last twenty-five years, in the production of steam power had not been in any way due to improvement in the evaporative economy of the boiler, which, on the contrary, was now greatly less than was common in Cornwall forty years ago in boilers carefully worked with slow combustion.

2. That this retrograde movement was the inevitable result of the harder working of boilers in our day, necessitated by increasing limitations of time and space, without the adoption of compensatory means to meet the changed conditions.

I likewise pointed out that while the demand on the productive power of boilers was increasing, this demand could not be accomplished by natural draft without a still further reduction of economy, and that the resort to forced draft for increase of power had hitherto resulted in further aggravating this loss of economy, and increasing the wear and tear of boilers in a greater ratio than that of the power produced.

I further described a system of forced combustion I had devised with a view to meet the demand for increased power in reduced space, and at the same time to reverse the conditions on which such increased power had hitherto been attained, viz: increased consumption of fuel, and wear and tear of boilers, and give, instead, this increased power with less wear and tear of boilers, and an economy approaching, if not equaling, that of the now almost historical high Cornish practice.

This somewhat ambitious endeavor I was led to make some few years ago, on what appeared to me a sound theoretical basis, guided practically by the experience of a similar attempt, instructive though unsuccessful, made many years before. The soundness of my theoretical basis, I had practically confirmed by trials, extending from 1882 to 1884, made chiefly in a multitubular boiler, 10 feet in diameter by 9 feet in length, having two furnaces, each 3 feet diameter, which I had built and erected for the purpose of testing it. The results obtained from this boiler gave me what I considered sufficient reasons for claiming the advantages for this system of combustion stated in my previous paper.

* * * * * * *

The case which chiefly supplies the facts stated in this paper is that of the steamship New York City, of the Direct West India Line, of Messrs. Scrutton, Sons & Co. I am indebted to Mr. Thomas Scrutton of this firm for his appreciation of the value of what I had then accomplished, and for having—undeterred by the halting opinions of those who are considered guides in such matters—placed an order in the hands of my firm, shortly after the date of the reading of my paper in 1884, for the refitting of the before-mentioned steamer with a boiler to be worked on my system of forced combustion.

The degree of confidence placed by Mr. Scrutton in my statements will be better understood when the nature of the voyages to be performed, and the size of boiler I proposed, are considered. The voyage is from London direct to the West India Islands, and through the Archipelago there, extending at intervals to Demerara and Honduras, the round voyage occupying, according to circumstances, from three to four and one-half months. The opportunities on the voyage for obtaining fresh water for the boiler are so limited that, as a rule, salt water only is used. The boiler I proposed, to replace the one in use, was to be considerably less in size and in furnace and heating surface measurements, and therefore insufficient for natural draft working. As the route in which the steamer makes her long voyages is not favored with the repairing shops to be found on most other routes, failure or injury to the boiler would have meant disaster.

The New York City is a steamer built, in 1879, on full-load lines for large dead-weight carrying; her dimensions being 260 by 34½ by 22½ feet, gross tonnage 1,724, and displacement, on full-load draught of 20 feet, 3,700 tons, nearly. The engines are ordinary compounds, having cylinders 33 inches and 61 inches diameter, by 33 inches stroke, and without an expansion valve on high-pressure cylinder. The original boiler, though worked as one double-ended boiler with two furnaces at each end, consisted of two separate cylindrical parts, each 12 feet 6 inches diameter by 6 feet 4½ inches in length, with large steam domes. These cylindrical parts were tied together at the distance apart of 4 feet 3 inches, this space, forming a dry combustion chamber, being closed in with an iron casing lined with fire brick.

* * * * * * *

The new boiler, Figs. 1 and 2, Plate III, supplied to the steamer to work with forced combustion, is single ended with three furnaces, and occupies so much less space in the ship that, after providing for an unusually roomy stokehold, sufficient space for 120 tons additional coal could have been got in former boiler room.

The following are the principal particulars of the two boilers :

	Original boiler.	New boiler.
Length without uptake	17 feet.	11 feet.
Diameter	12 feet 6 inches.	14 feet.
Steam domes	two	none.
Number and diameter of furnaces	four, 3 feet 5 inches.	three, 3 feet 4 inches.
Number, length, and diameter of tubes	372–6 feet 4½ inches by 3½ inches.	210–8 feet by 3 inches.
Tube surface	2,173 square feet.	1,319 square feet.
Length of fire bars, over all	5 feet 6 inches.	4 feet 1½ inches.
Aggregate fire-grate	75 square feet.	36 square feet.

The diameter of the new boiler is somewhat greater than is required for the size of furnaces or number of tubes. The diameter of the tubes also is larger than would have been used had I not undertaken in the contract to develop a certain power with natural draft. The size is therefore a compromise between chimney and forced-draft proportions. The air-heating tubes for each furnace are 40 in number, 2 feet 3 inches in length, and 3¼ inches external diameter, they also being proportioned, so far, in view of the boiler being worked with natural draft. The air space in the fire grates was reduced in width by side pieces to rather less than 2 feet 11 inches across, so that each fire grate was, with 4 feet 1½ inches length of bars, 12 square feet in area. A twofold object was sought for in using these side pieces, one being to prevent the too rapid combustion of the fuel at the sides of the furnaces, and the other to reduce the heat somewhat at a part where the plating is unfavorably placed for throwing off the water evaporated, being below the centre line of the furnace.

The boiler was fitted on board in September, and, after the loading of the steamer for outward voyage, was tried for about four hours under various air pressures before leaving on October 13, 1884. * * * As the engines had not in any way been altered, the valves remaining exactly as on previous voyages and the propeller untouched, an unusually good opportunity was afforded for comparing the performances of the boilers. The average revolutions of the engines with the natural-draft boiler were 56, and the I. H. P. 564. With the new boiler and forced draft it was found on first trial that 64 revolutions could be easily maintained with the Scotch coal then used. The indicator on board being out of order no diagrams were then taken, but from diagrams taken on a subsequent voyage it was found that, with the same load draught, 760 I. H. P. were required to give 64 revolutions.

The steamer put to sea immediately after trial, and made a good run to Trinidad without stoppage. The average revolutions on the voyage were 57 and the consumption 11 tons per twenty-four hours. The average speed would have been higher but for the formation of clinker, and inexperienced firemen. It was attempted on the voyage to run the fires twelve hours without cleaning, but the Scotch coal, which was of inferior quality, contained too large a proportion of clinker to permit this, and eventually it was found to be necessary to clean fires every six hours to keep them in good working order. It may be noticed here that with the Welsh coal of fair quality, which has been used in the steamer for the last twelve months, the fires can be kept in good order, cleaning every twelve hours.

After more than seven months' continuous working, in compliance with the request of my firm, Messrs. Scrutton had a report prepared by their superintendent engineer, Mr. Nicolson, * * * of the results of the working of the new boiler under forced draft up to the date of the report, 11th June, 1885, with a comparison of results from the natural-draft boiler under same conditions. In this report the following particulars are given of four voyages made under similar conditions and affording a fair comparison; two being made with the natural-draft boiler and two with the forced-draft boiler.

* * * * * * *

ORIGINAL BOILER WITH NATURAL DRAFT.

Voyage.	Draught.				Average revolutions.	Average I. H. P.	Coal.	Consumption per 24 hours.	Weather.
	Aft.		Forward.						
	Ft.	*in.*	*Ft.*	*in.*				*Tons.*	
1. Homewards	20	3	19	3	56	564	Welsh	13½	Fair.
2. Outwards	20	4	18	10	59	Not taken.	Ryhope.	15	Fair.
NEW BOILER WITH FORCED COMBUSTION.									
1. Outwards	20	4	18	10	57	Not taken.	Scotch	11	Fair.
2. Homewards	20	3	19	6	60	623	Welsh	9½	Fair and head wind.

Mr. Nicholson's report in regard to (2) voyage with forced-draft boiler and Welsh coal is as follows:

> Comparing this run with (1) voyage of original boiler, also with Welsh coal, it is evident that, to have maintained on that voyage 60 revolutions and 623 I. H. P. with that boiler the consumption could not well have been less than 15 tons per day, so that it appears to be a fair conclusion that the smaller boiler, with this system of forced combustion, has not only maintained a higher power than the larger natural-draft boiler, but has at same time reduced the consumption of coal with the same engines from 2.24 pounds to 1.42 pounds per hour, without taking into account the power for working the fan engine, which, being supplied from the boiler, should correctly be added to the I. H. P. of main engines.

On the next voyage out and homewards after the report referred to was made, a still higher result was obtained, as given in the following extract of a letter from Messrs. Scrutton to my firm of 22d August last:

> The New York City having completed on 7th August another voyage to the West India Islands and back to London, we have pleasure in informing you that the results

obtained from your boiler with forced combustion show continued improvement. The average I. H. P. of the outward and homeward voyages, ascertained by our superintending engineer, is 628, including 6 I. H. P. for the fan engine. The consumption of Welsh coal has been throughout the voyage 9 tons per 24 hours. The boiler continues in perfect order. The results altogether are most satisfactory.

This consumption at sea is at the rate of 1.337 pounds per I. H. P. per hour, with a rate of combustion giving 17.4 I. H. P. per square foot of fire grate. On the last completed voyage a still higher rate of combustion was made by a new engineer, who, without any previous experience in forced draft, ran the engines for some days on the passage to Barbadoes at 62 revolutions, with an indicated H. P. of 706, including fan power, the coal consumption rising to 11 tons per day, this rate of combustion giving 19.6 I. H. P. per square foot of fire grate, with a coal consumption 1.454 pounds per I. H. P. per hour, the coal being reported as "small and inferior."

* * * * * * *

The following statement by the late chief engineer of the New York City, Mr. John Pettigrew, shows further that a greatly higher rate than 19.6 I. H. P. per square foot of fire grate can be obtained by this system of combustion without difficulty. The letter is dated 15th March, 1886, and is addressed to Messrs. Scrutton, from whom I received it:

As requested, I now beg to describe some tests I made of the power of the boiler of the New York City, with Howden's patent system of forced combustion, while at sea under my charge. As you are aware, I never had occasion to test the utmost power the boiler could be worked to, but on one accasion I tried, by order, the power required to give 64 revolutions to the engines with the vessel fully loaded, and found it was 760 I. H. P. I have, however, used occasionally a much higher rate of combustion than was required to maintain the revolutions at 64 per minute, having frequently, as a feat, begun to clean a fire with steam on the gauge at 80 pounds, and have raised the steam to 85 pounds, while blowing off at the safety valves, before the operation was completed. This was done by simply charging the other two furnaces, after running the pricker through their bars, with a good supply of fresh fuel, and beginning, as soon as the fresh charge was in flame, the cleaning of the third fire, which had been allowed to burn down. As the fan continued running at its usual speed, and the air supply was cut off from the fire being cleaned, the air pressure increased and the two fires consequently received a greater supply, which, with the heavier charge of fuel on the two furnaces, was sufficient to increase the combustion so as not only to maintain the pressure, but to increase it, as stated, until steam blew off at safety valves at 85 pounds pressure. The engines during this time were left running at their usual speed, no change being made in the admission, and as the steam increased in pressure the engines would also increase in speed. Though I never took diagrams when testing the combustion as described, I know they could not have been working at less than 630 I. H. P.

This increase of pressure, * * * from the combustion of two fires on a total of 24 square feet of grate surface, shows an evaporative power from a square foot of fire grate of probably not less than 30 I. H. P. Those who have experienced the large drop in pressure when cleaning fires in ordinary boilers will appreciate the value of the facts just stated. These facts also conclusively sustain the very important claim made in my former paper for this system of forced combustion, viz, the absence of any injurious rush of cold air through the furnaces and tubes when a furnace is being operated on, the detrimental cooling effect of which, even in natural draft boilers, is very noticeable.

From such results as those which have been given, and the experience gained from the continuous working of this steamer for nearly eighteen months, I can now venture to say, with some confidence, that an evaporative power per square foot of grate can be obtained with ease and safety from this system of forced combustion in continuous working at sea, under ordinary conditions, of at least 25 I. H. P. with compound engines at about 80 pounds pressure, and 30 I. H. P. with triple expansion engines at about 140 pounds pressure, at rates of consumption not exceeding, whatever less they may be, 1.35 pounds and 1.1 pounds respectively per I. H. P. per hour.

* * * * * * *

The feature in this system of combustion, which makes such great concentration of power possible in an ordinary mercantile steamer on everyday work, is that of its economy. * * * That the system should be easily worked on a large scale, and be, as it were, self-preservative, were likewise indispensable conditions, as any system of forced draft giving extra trouble in working, and not capable of enduring continuous working over the longest voyages, could not be desirable for sea-going steamers.

In my first attempt at forced combustion, in 1862, which was that of forcing air under pressure into a closed ashpit, I was unable to obtain either a workable or an economical system. To produce complete combustion by this mode of working, at a rate greater than is attainable by chimney draft, the fires must be sufficiently light to allow enough free oxygen to reach the combustible gases above the fuel, but the excess of air necessary to accomplish this is so great as to reduce the evaporative economy much below that obtainable by natural draft. When, on the other hand, a thick fire was used to prevent the too abundant passage of air through it, the smoke therefrom was excessive, and a large quantity of carbonic oxide escaped unconsumed, while there was much trouble with the fire bars owing to the most active combustion being, not on the top of the fuel, but near to the fire bars. Though the evaporative economy was as a rule higher with the heavier than with the lighter fires, it was still less than that obtainable by ordinary chimney draft working.

* * * * * * *

There were other difficulties, such as requiring to shut off the air when the furnace door had to be opened. If this system is worked so that the air is prevented from passing through the fire bars and fuel sufficiently to produce any pressure in the furnace by reducing the air spaces between the bars, and the chimney draft therefore capable of drawing air by the furnace door, some of the difficulties mentioned will disappear, but, in such a case, though the air may be supplied under the bars by a fan with pressure, it cannot be termed an example of "forced draft," taking this conventional expression to signify, as it does throughout this paper, a rate of combustion, unattainable by chimney draft, produced by an artificial supply of air.

* * * * * * *

My first efforts at improvement were directed to obtain a workable and controllable furnace, with air pressure above the furnace bars as well as below, and with this important practical provision, that when a furnace door was opened the air pressure would cease, and a rush of air be prevented from entering into the furnace when it was being operated on. This I accomplished by devising the air pressure casing to cover both the furnace door and ashpit, using an inner furnace door as the proper door of the furnace, and the outer door for retaining the air pressure between the two doors when closed, and for relieving the pressure when opened. This first stage made a workable furnace, but not one properly controllable or highly economical. To effect these further important features, I found it necessary to separate the admission of air above the fuel from that below the fuel, so that the admissions could be made in different quantities and with different pressures at command. This was secured by the division in the air casing separating the ashpit from the air casing over the furnace door, and by the use of separate air-regulating valves for these respective parts of the furnace. These additions made the furnace both workable and controllable in the highest degree, and capable of effecting, if rightly used, the highest possible economy in combustion when, in conjunction therewith, the supply of the air for combustion is heated by the escaping waste gases to the greatest degree attainable therefrom. This heating of the air for combustion by the waste gases is an element of the first importance in effecting a high economy of fuel in forced combustion, and the one which makes possible or increases the beneficial effects of other combining elements. These are not to be measured only by the direct recovery of so much heat that otherwise would be lost, but also by their effect in increasing the average temperature of the furnace, which again not only adds to the evaporative efficiency of the boiler, but also allows of a more facile and rapid union of the oxygen of the air with the gaseous products and the carbon of the fuel, so that actually *less weight* of hot air than of cold is required to effect the combustion of an equal weight of fuel in a given time. This further raises the degree of evaporative economy and power of the furnace, making an economy and rate of combustion possible which otherwise would be unattainable.

In the New York City the recovery of the heat from the escaping gases has not been effected to the extent it could have been, so much having been sacrificed by the adoption of proportions, as already explained, to ensure certain results by chimney draft. That a still higher economy in fuel could be obtained from the boiler of the New York

City by utilizing a greater proportion of this heat is therefore absolutely certain. The air of combustion in this steamer is heated directly by the waste gases in the heating chamber from 180° to 200° above temperature of stokehold. This is further increased by its passage through the furnace front plate and interior air boxes, which are preserved by the air carrying off their heat into the furnace, which it enters at a temperature probably averaging about 450°.

I take the opportunity of referring here to the remarks made by Mr. Milton in his paper, read at last year's meeting, "On the Efficiency of Steam Boilers," on the disadvantage, as he supposes, of my practice of heating the air of combustion by the waste gases instead of the feed water; estimating, as he does, the abstractive powers of water and air to be as the products of their specific gravities and specific heats, thus making water 3,500 times more efficient than air. If Mr. Milton's error had been only 1,000 times less than it is—that is, if water had been even 3.5 times more efficient than air, I would probably not have been now addressing you, as the success of my system is largely due to the fact that air, as I use it, is a greatly better abstractor of heat than water passing through a feed heater.

I am able to give the relative values in this respect from actual trial sufficiently correct for practical purposes. In the New York City, the heat abstracted by the air for combustion from the escaping gases in the air-heater, on ordinary sea working, averages 190°. Taking the air used for combustion at 18½ pounds per pound of coal we have $190° \times 18.5 \times .238 = 836.57$ units of heat directly recovered by this air from the waste gases per pound of coal consumed. In a boiler which I lately tried, where the whole of the escaping gases passed through a horizontal multitubular feed heater, and where the water evaporated from 42° was 10 pounds per pound of coal consumed, the temperature of the feed water, leaving the injector at 114°, was raised, on an average, only 25° in passing through the feed heater. This gives $10 \times 25° = 250$ units of heat recovered by the feed water per pound of coal consumed. This does not, however, exhaust the case in favor of the air as a better heat abstractor, for the feed heater referred to had a tube surface of 304 square feet with only 75 pounds of water passing through it per minute at a velocity of .025 feet per second, while the New York City's air-heater has only 230 square feet of surface with an average of 275 pounds of air passing through it per minute at the velocity of 25 feet per second. These facts will enable Mr. Milton to readjust his figures as to the comparative efficiency of water and air as heat abstractors.

* * * * * * *

In the furnace of a steam boiler, worked in the ordinary way with the respective air admissions mentioned by Mr. Milton, the relative resulting temperatures would actually be reversed. If 12 pounds of air per pound of fuel were introduced into a boiler furnace in operation in the ordinary manner, a much lower temperature than is usual in boiler furnaces, and a more wasteful combustion, would, for obvious reasons, result If 18 pounds of air per pound of fuel were admitted in an equal time to the same furnace a considerably higher temperature and less wasteful combustion would follow, and with 24 pounds of air both temperature and economy would be higher still. I am led to the conclusion that 24 pounds of air admission would give the best result, from the fact that 24 pounds of air admission appears to be about the average in well-managed furnaces worked in the ordinary manner. Now, the reason of this is not because such a large proportion of air is desirable, but because it is necessary in furnaces worked in the ordinary manner, for if the same active combustion could be effected in the same time with less air, a proportional increase of temperature and economy in fuel would inevitably follow. Universal experience, however, shows that to obtain a certain evaporative power from a boiler worked in the ordinary way about 24 pounds of air must be used. * * * The apparent anomaly, of the worse practice theoretically, giving the better result, arises from practical conditions due to the manner in which the air is admitted to the furnaces and the behavior of the gases in combustion, which, however, cannot be gone into in detail in this paper. Temperature in furnaces does not depend primarily on the weight of air used per pound of fuel consumed, even when that combustion is judiciously effected, but on the quantity of fuel brought under combustion in a given time and space; the greater the quantity consumed the higher the temperature.

Returning to the consideration of the effect of the manner in which fuel is burned, I would point out that though it is impossible in the large scale of a boiler furnace to reduce the proportion of air very closely to the theoretical quantity sufficient for the complete combustion of the fuel, yet a very large reduction can be made on the proportion now used, by a different mode of making admission. Except for the hydrocarbon gases, which apparently cannot be consumed without a considerable excess of oxygen, very little excess would be required for the complete combustion of the solid carbon by the adoption of effective means for combination. A large dilution of the carbonic acid in the furnace by admission of excess of air is only necessary when furnaces are worked in the ordinary manner. What is wanted is to bring the air for combustion *simultaneously* in contact with the gaseous and solid fuel *over the whole surface of the furnace* at a velocity that will insure its intimate mixture directly with the fuel. In such circumstances a greatly reduced proportion of air will suffice for combustion, more especially if the mode of effecting combustion is at same time so arranged as to gasify the carbon to a large extent. I have endeavored, in carrying out my furnace operations, to approximate as nearly as possible to these conditions, and to work the furnace as, what may be termed, a combined quick-gasifying and complete-combustion furnace, by the following means: The air in the ashpit, with a given area of air space through the fire bars, and a given average depth of fuel, is maintained at a pressure designed to pass a quantity of air through the fuel sufficient to gasify it and bring it to the surface largely in the form of carbonic oxide. The air in the casing between the two furnace doors is maintained at a considerably higher pressure than in the ashpit, and is thus received by the distributing boxes inside the furnace plate and inner furnace door. The air, then, at a considerable temperature, and at a high velocity, issues in minute streams from small holes in the interior side of the air boxes, their aggregate area being proportioned to the normal work of the furnace, and their position arranged to cause the air to strike the fuel with force equally over the surface within the limits of the fire bars, as represented in Fig. 3. By means of these differential pressures used as described, the weight of air required for the complete combustion of a given weight of fuel can be made much less than is necessary in an ordinary furnace, while with the complete stage of combustion being chiefly on or above the surface of the fuel, a clear white flame and intense heat is generated where most effective for radiation, and most innocuous in its effect on the furnace bars.

* * * * * * *

The practical difficulties which have arisen from working this system at sea over eighteen months by inexperienced and sometimes careless firemen, have been greatly less than I anticipated. They have in no case been peculiar to the system of working, and are of so little conse. quence that it is unnecessary to occupy time in mentioning them.

* * * * * * *

In my paper of 1884, in referring to other systems of forced combustion within my knowledge, I pointed out the grave disadvantages which must attend the use of the closed, or air pressure stokehold system, used so extensively in our war ships. Since then I have had occasion elsewhere to refer still more strongly to this system as one essentially injurious to boilers. It therefore devolves upon me to show sufficient cause for holding such opinions. The importance of the subject will excuse my doing so at some length. It is a singular circumstance that though this system has been fitted in a number of vessels for several years, I believe I am strictly correct in saying that for forced draft rates of combustion it has never yet been proved by 24 hours' continuous working at sea. The case of those steamers belonging to Mr. Alfred Holt, which are fitted with closed stokeholds and which have been worked more or less at sea, is not a case in point. These steamers are not worked at a forced draft rate of combustion. Mr. Holt has favored me with particulars of two of these steamers, the Hector and the Anchises. The Hector develops 780 I. H. P. from 90 square feet of grate in a boiler having six furnaces and 2,504 square feet of heating surface, and the Anchises 900 I. H. P. from 90 square feet of grate in a boiler with six furnaces and 3,101 square feet of heating surface, being respectively 8.66 and 10 I. H. P. per square foot of grate per hour.

With this rate of combustion the injurious effects arising from this system of forced combustion are not developed. The boilers used by Mr. Holt are also, from their design, peculiarly fitted to withstand the injurious effects of the cold-air admission.

The Holyhead mail steamers are also fitted with this system. The boilers are, like those of Mr. Holt's steamers, quite capable of supplying full steam by natural draft, and the supply of air by the fans is only used when the weather or other circumstances are unfavorable for a good natural draft. The run each way occupies about 3½ hours, and the steamers are laid up one week out of every three. The rate of combustion gives about 6.75 I. H. P. per square foot of grate, but this is with low pressure simple engines.

These examples and similar ones in America, where working a fan in an open stokehold has been long in use, do not therefore fall within the cases of forced draft, so that the question whether boilers can be worked with this system, when the steamers are put to the use for which they were built, remains yet to be proved. Meantime, in the absence of direct proof, the effects of this system can only be judged of from experience obtained from analogous cases, and my experience of such cases, which has been on a somewhat extensive scale, leads me decidedly to the conclusion that this system is unfitted for the ordinary working of boilers at sea.

The cause of injury to the boilers, common to both the closed stokehold system and to the cases within my experience, is that of the sudden cooling of the interior of the boiler by a rush of cold air immediately after being under a high furnace temperature; but, in those boilers in which I have seen the ruinous effects of this sudden change of temperature, being worked by natural draft, the rush of cold air through the boiler was much less in velocity and volume than obtains in boilers with closed stokeholds under air pressure. The boilers to which I refer were fitted with their engines by my firm a few years ago in steamers of over 4,000 tons, whose names it is not necessary to give here. The boilers in each steamer were ten in number, made to the owning company's specification on a certain patent design somewhat of a locomotive type, but without sides or front to the fire-box part, which was formed of brick-work. The maximum working pressure was 125 pounds, and the boilers were designed to supply steam to work the engines up to 3,300 I. H. P. On trial, with the boilers quite clean and containing fresh water, they supplied steam steadily and well, and worked continuously over the whole day without the slightest leakage at any part, or sign of injury. Starting thus on a voyage to Calcutta, the power being reduced to about 2,100 I. H. P., the boilers ran for a number of days without trouble, but as soon as the formation of a very slight scale on the tube plates began and the water increased in density by replenishing the waste from the sea, the increase of temperature on the tube plates exposed to the flame rendered these so much more sensitive that on the opening of a furnace door the sudden rush of air across the furnace, a distance of 6 feet 6 inches, struck the tube plate, with a difference in temperature sufficiently great to cause a sudden contraction of the tube plate and unequal contractions of this thicker tube plate and the thinner tube ends, so that a general leakage at the tubes took place. This leakage once begun could not by any means be stopped, so that the dust and soot from the fire adhered to the damp plate, and in a short time accumulated to such an extent as almost to close up the tubes and reduce the power of the boilers to a small fraction. The only course then left was to draw the fires, clear and tighten the tubes with an expander, and then go on again to repeat the above process, sooner or later, even with the most careful management. To work these boilers, without continual trouble and great expense, even at a further reduced power, it was found necessary to use fresh water only and to protect the tube plates as far as possible by loop-holed brick-work. A large multitubular boiler, having two furnaces 3 feet in diameter, was kept employed in supplying steam from sea water for condensation in order to make up the entire waste from fresh water. Notwithstanding these precautions and after many expensive repairs, the boilers of the first of these steamers were, after eighteen months' working, so much injured that new boilers of ordinary form were ordered to replace them. Before their completion this steamer was lost in a voyage across the Atlantic, and the new boilers were fitted into the second steamer a few months thereafter, the boilers of this latter vessel having suffered in a like manner to that described. These boilers, though ot a type more liable to injury than the usual marine type, show what would undoubtedly take place in any boiler in which a large volume of comparatively cold air suddenly impinged on the interior plates, especially the tube plates, which, until the moment of impact, had been under a high furnace temperature. That the vast volume of air rushing through the furnace of a boiler worked on the closed stokehold system, with forced combustion, would strike the tube plates cold enough to cause serious damage, may be inferred from the area of the volume and its velocity, the former that of the furnace door, the latter 60 to 70 feet per second. This conclusion is indeed not left to mere inference—it is a fact within the experience of most sea-going engineers working with chimney draft, that when considerable scale accumulates on a back tube plate of an ordinary marine boiler, if a furnace door is suddenly opened under certain conditions of draft the rush of cold air causes the tubes to leak.

I called attention two years ago to the facts recorded by Mr. R. J. Butler, in his paper of 1883, "On the Steam Trials of the Satellite and Conqueror under Forced Draft," when even after trials not exceeding three hours' duration, with boilers perfectly clean and containing fresh water, and producing less effect in I. H. P. per square foot of grate than the boiler of the New York City has been working at continuously at sea for eighteen months with salt water, the boilers in both steamers were leaking at the tubes, a result seriously significant. It will be remembered that the boilers just described, which suffered so greatly from the effect of the impact of cold air, did not show the slightest injury on a prolonged trial, nor for some days after they had been at sea, while in the Satellite and Conqueror a few hours' trial, under the most favorable conditions, produced the injurious effects described. I am aware it is stated that it is not intended to work the steamers with this forced draft at sea unless emergencies arise to require it, and the boilers are made large enough to supply steam for full power by natural draft. If so, then the proper advantages of forced combustion, reduction in weight of machinery and space occupied, are given up, and the vessel cumbered with an expensive and troublesome arrangement, well known to be at least wasteful in fuel, for the prospective advantage of it being used on emergencies. But I must ask, will even this prospective advantage be realized? I am convinced it will not. I believe that after a steamer fitted on this system has been at sea for some time with natural draft, and the boilers have accumulated a slight scale, if it were attempted to use forced draft on an emergency, the boilers would soon be rendered useless and the vessel left helpless.

Another difficulty I cannot avoid reference to, which is never experienced on trials of a few hours or on short sea passages, but which must be faced at sea with continuous working, is that of cleaning fires. With the large consumption required for this system of forced draft, fires could probably not run for more than six hours without cleaning. Would it be possible to clean a fire with a volume of cold air of the area of the furnace door rushing through the furnace and tubes at the velocity due to 1½ inches or 1 inch water pressure? Supposing the boiler was not injured by the terrible scour of cold air, it would certainly be cooled down to a serious extent by the furnace and tubes, for the time being, acting as a condenser. The only alternative would be to reduce the air pressure, for the time being, to that of the atmosphere, if this could be done with safety in a boiler room in connection with others through a common funnel. Take a steamer having thirty-six furnaces divided into four separate air pressure compartments, cleaning fires as mentioned, six furnaces would require to be cleaned every hour. This would place at least half of the boilers continuously under very low combustion, so that whatever alternative, whether this or the worse, was adopted, the cleaning of the furnaces on this system under continuous working, could not be other than a serious practical difficulty.

* * * * * * *

Putting aside altogether the question of injury to the boilers and recurring to the fact that the steamers of the navy which are fitted with this forced draft system have boilers of the usual size, so as to steam full power by chimney draft, let us assume that with forced draft the boilers of a steamer of the larger class could supply steam to drive the engines continuously at sea at a power 20 per cent. above that of full chimney draft power, without trouble in cleaning fires or the slightest injury to the boilers. I believe I make no over statement when I say that, even in such a case as here assumed, the same steamer fitted on my system of forced draft, and with the boilers required for equal power would steam at equal speed three times the distance it could do with the closed stokehold system of forced draft. This is owing, first, to the greatly reduced size and weight of boilers, water and fittings required with my system, leaving room for larger carrying space; and, secondly, to the much smaller consumption of coal required to produce the same power. The vital importance of such an effect in the reduction of weight and space and coal consumption in war-ships does not require illustration here. The difficulty in building ironclads on favorable forms for economical propulsion, and securing at the same time sufficient protection in thickness of armor plate, would be greatly relieved by the reduction of 1,000 tons in the weight of the necessary machinery and coals in one of the larger ironclads. Still keeping out of view the vital difference between using a safe system adapted for everyday work and an unsafe system unsuited for everyday work, the advantages of possessing high-speed cruisers, able to run continuously with ease at the highest speed, and to keep the seas, as I have said, for thrice the time they could with the present system, I leave to be estimated by naval officers and others experienced in handling such ships.

For steam yachts the use of my system of combustion would make a speed possible, with a reduced weight of machinery, quite unattainable with present arrangements, while the absence of smoke, the perfect control of the steam—so that blowing off at the safety valves under any circumstances can be prevented—also, the power to reduce the evaporation at will to the lowest point sufficient to turn the engines, and to lie at rest for many hours with the combustion practically stopped, and thereafter to go on at full speed at one minute's notice, are all advantages of a very important character, not only for yachts, but for any class of steamship, and of special importance in war-ships.

In my paper of 1884, I gave an example of the reduction in size and number of boilers which, on my system, could safely be made on such a steamer as the Oregon, then the most powerful passenger steamship afloat. The boilers in that ship were nine in number, 16 feet 6 inches in diameter, and 18 feet in length, each having eight furnaces, 3 feet 6 inches in diameter, or 72 in all, with an aggregate fire-grate surface of 1,512 square feet. The boilers with which I proposed, on my system, to maintain an equal power, viz, 12,000 I. H. P., were six in number, 15 feet in diameter by 18 feet in length, with six furnaces in each, 3 feet 9 inches diameter, or 36 furnaces in all, with an aggregate fire-grate surface of 641 square feet. It will probably be remembered that, when I proposed to give an equal power with such a reduction in the boilers of this ship, it was considered to be quite impracticable. I need only point to what has been accomplished continuously for a period of eighteen months in the cargo steamer New York City, on much longer runs and where a high power and speed are not sought for or attempted. 12,000 I. H. P. from 641 square feet of fire-grate is only 18.75 I. H. P.

per square foot, a rate which has been surpassed in the New York City.

It is therefore quite evident that a considerably greater reduction in boilers than I then proposed could be made in such a steamer as the Oregon with an organized staff, and arrangements for the attainment of a high speed. In concluding with an illustration of the commercial advantage of such an arrangement as I proposed in such a vessel as the Oregon, I will, to keep well within very safe limits, assume the boilers to be in size and number what I formerly proposed, and instead of the lower rate of the New York City I will take the consumption at 1.5 pounds per I. H. P. per hour, and also instead of assuming the rate of the Oregon, with her natural draft boilers when developing at sea 12,000 I. H. P. at 2.6 pounds, will assume a rate of only 2.28 pounds at that power. These rates give a reduction in coal consumption of exactly 100 tons per day in favor of the forced draft boilers. Taking these rates of consumption and numbers and sizes of boilers as a basis of comparison, I find from a calculation of the weight of the reduced number and size of boilers, including water, mountings, uptakes, piping, flooring, and other necessary fittings, that they could not be less than 450 tons under that of the original boilers. The reduced space occupied by the fewer boilers under main deck gives room for 1,250 tons cargo of 40 cubic feet, while the 'tween decks and deck house, which would be set free for passengers, would accommodate at least 80 first and second class passengers. The coals carried per voyage each way being 800 tons less, would leave additional room for 800 tons of cargo of 40 cubic feet per ton.

The more convenient coaling arrangement secured—not only by the reduced number, but by the smaller size of boilers—and the consumption, less by 100 tons per day, should reduce the number of firemen and trimmers by not less than 60, and thus set free berth room for at least 40 steerage passengers. Taking ten round voyages per annum between Liverpool and New York, with seven days in each port and eight days each way at sea, or 30 days for each round voyage, there would be per annum 160 days steaming, 140 days in port for loading and discharging, and 65 days laying up for yearly overhaul and repairs. Supposing the extra passengers and cargo are obtained, the savings and increased earnings at the following rates, which provide for a further decrease on the present rates already abnormally low, would amount to—

On round voyage.

	£
Saving in fuel at 10*s*. per ton, put in bunkers Liverpool and New York, 1,600 tons at 10*s*	800
Cargo, weight and measurement, 4,100 tons at 20*s*	4,100
160 first and second-class passengers, less cost of victual, £10 each	1,600
80 third-class passengers, less cost of victual, £3 each	240
Pay and victualling of 60 firemen at £5 per month	300
Total for round voyage	7,040
Total for ten round voyages	70,400

PLATE III.

FIG. 1.

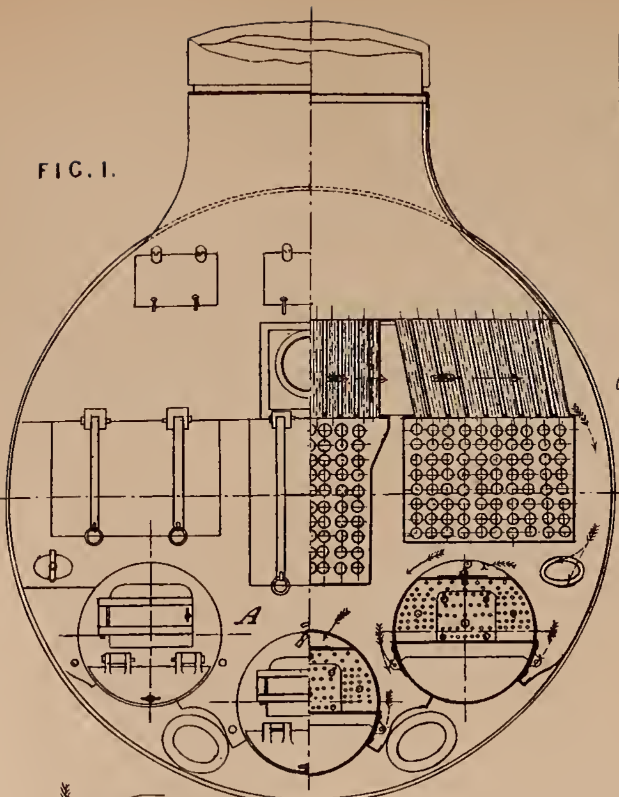


FIG. 2.

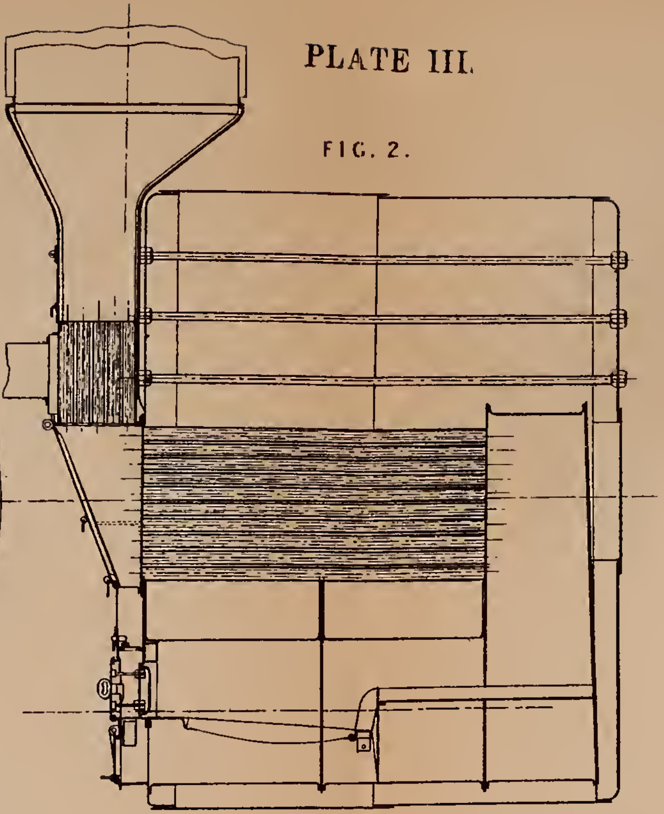
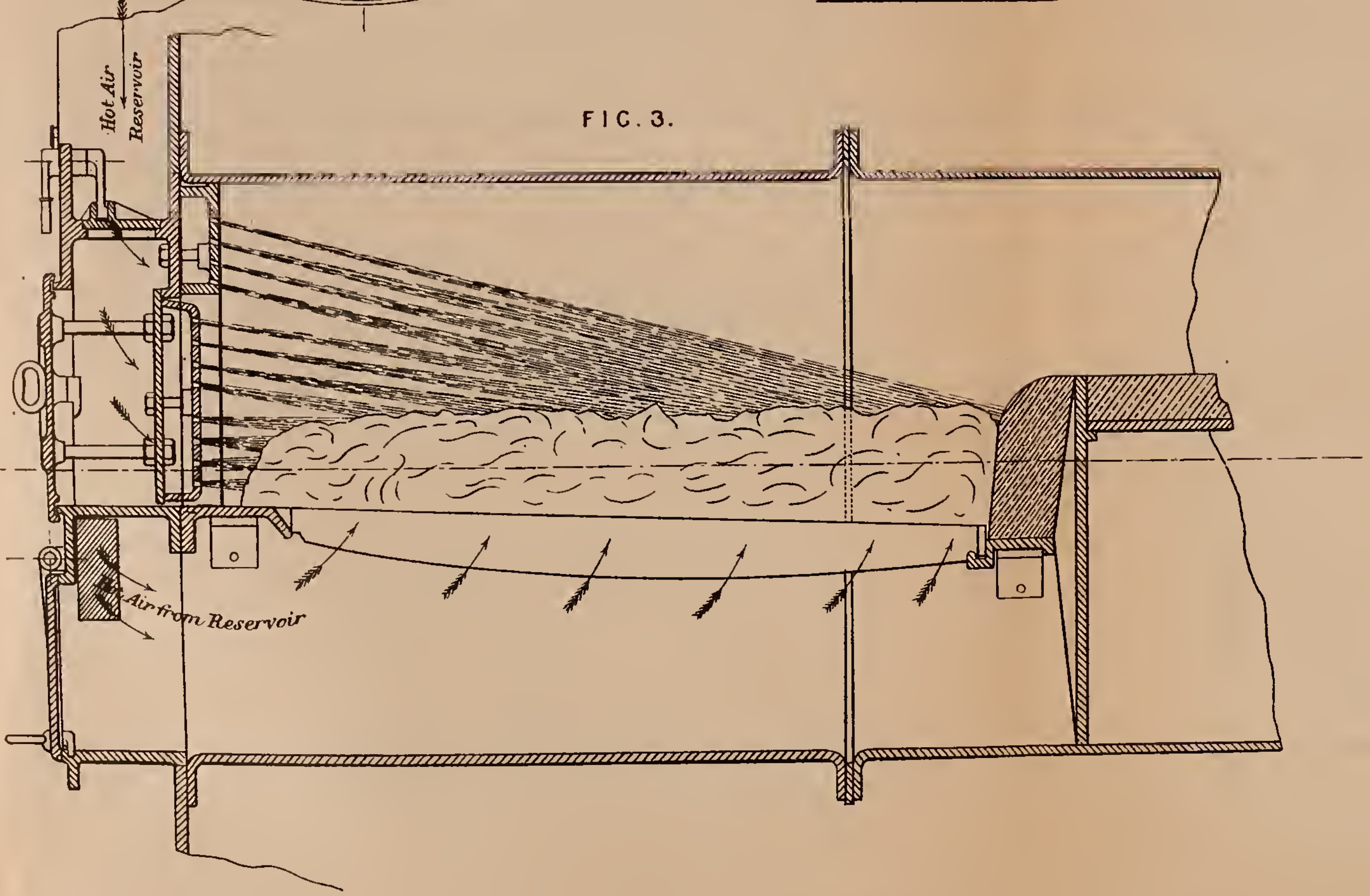


FIG. 3.



DISCUSSION.

Mr. J. Wright. As the two papers which we have just heard read are on one of the most burning subjects of the day, connected with marine engineering, no doubt many gentlemen here wish to take part in the discussion, and so I shall make my remarks as brief as possible. Mr. Sennett has fairly stated the case on behalf of the closed stokehold; his statements are all based on very carefully taken facts, and the few suggestions that he has made beyond the facts are put forward modestly as suggestions, and not, as he says, with any attempt to dogmatize. If Mr. Howden had been content to give us a description of his system as applied to the City of New York, I should have been disposed to confine my remarks to congratulating him on the very considerable success he has attained in that ship. Her old boiler may have been bad and badly worked, but there is no doubt the new boiler he has supplied is a very great improvement on the old one. I had an opportunity of getting a copy of the paper early this morning, and I have made a few calculations. First of all I should like to draw your attention to the very small size of fire grate in the boiler, and I find on going through Mr. Howden's paper that he has almost entirely based his calculations upon the area of fire grate, ignoring entirely, or nearly so, the question of cubic capacity of boiler, and weight of boiler. I want to give you a few particulars, comparing them on the same basis. In the first place I should like to say that I think his system can scarcely be called forced combustion at all, because it is really a very moderate rate of steaming. I will take the power which he has given on page 81, 623 horses and 9½ tons consumption per day, and taking that in a fire grate of 36 square feet, it is only a rate of consumption of 24½ pounds of coal per square foot of grate per hour. I will take the highest rate given, namely, 11 tons per day; that, on the same basis, is only 28½ pounds of coal per square foot of grate per hour. With ordinary draft it is a very common thing to burn from 21 to 22 pounds of coal per square foot of grate per hour, on a very much larger proportion of grate than there is in that boiler; with the steam jet applied to boilers we used to burn from 28 to 30 pounds without any difficulty. In the Howe, which was mentioned in Mr. White's paper the other day, under forced combustion, she burnt 33½ pounds of coal per square foot of grate per hour on a very large fire grate. I think I have shown you the rate of combustion is a very small rate, and it ought, therefore, to be a very economical rate. I should like now to call your attention to the proportion between the fire grate and the heating surface. The ordinary proportion of fire grate to heating surface in naval boilers, and I believe also in the ordinary boilers of merchant ships, is from 27 to 30 square feet per square foot of fire grate. In the boiler of the City of New York the proportion is between 42 and 43 square feet; I could not calculate exactly, because the boiler drawing does not show it sufficiently; that is to say, the proportion of heating surface to fire grate in the City of New York is 45 per cent. more than the ordinary proportion, and it is bound, therefore, to be a very economical boiler. I should like now to refer to the question of the cubical capacity of the boiler in comparison to the amount of power given out. The cubical capacity of the boiler of the City of New York is 1,693 feet. I will just take two cases, to save time, of naval boilers, one the Amphion and the other the Howe. The cubic capacity of the Amphion's boiler is 1,331 feet; one boiler of the Howe 1,344 feet; that is to say, the City of New York boiler is 27 per cent. greater than the boiler of the Amphion, and 26 per cent. greater than the boiler of the Howe. I wish you would keep these percentages, gentlemen, in your mind. The next thing is the horse-power which has been developed. There seems to be a most unfortunate reluctance on board the City of New York to take diagrams, but we have got a few statements. I will take the power given on page 81 in the first instance, 623. That, of course, Mr. Howden will say is a very low power; I will take it for granted it is, and go to a higher power by and bye. Taking the 623 as the power given out by the City of New York, one boiler of the Amphion, 27 per cent. smaller, with natural draft, gave 706 horse-power; one boiler of the Howe, with natural draft, gave 644 horse-power, and one boiler of the Howe, with forced draft, gave 977 horse-power. Taking the horse-power per cubic foot of boiler it comes to this—per cubic foot of boiler in the City of New York it was .368, in the Amphion with natural draft .530, and in the Howe with natural draft it was .479; in the Howe with forced draft the horse-power per cubic foot of boiler was .727. That is to say, the horse-power given out in the Amphion with natural draft per cubic foot of boiler was 44 per cent. more than in the City of New York with Mr. Howden's forced combustion. In the Howe with natural draft it was 30 per cent. more than the City of New York, and in the Howe with forced combustion it was 97½; in round numbers twice as much. The highest power given for the City of New York is 760. I do not see that there is very exact evidence given as to the 760, but we will take it as being the most power the boiler can give. Taking it on the same basis of cubic capacity of boiler, I find that that gives .449 horse-power per cubic foot of boiler; that is to say the Amphion's boiler, with natural draft, gave 18 per cent. more than the maximum power of the City of New York with forced combustion; the Howe's boiler with natural draft gave 6⅔ per cent. more than the City of New York maximum, and the Howe with forced combustion gave 62 per cent. more than the City of New York with forced combustion. I should like to read a few words beginning at bottom of page 90 of the paper: "I believe I make no over-statement when I say, that, even in such cases as here assumed, the same steamer fitted on my system of forced draft, and with the boiler required for equal power, would steam at equal speed three times the distance it could do with the closed stokehold system of forced draft. This is owing first to the greatly reduced size and weight of boilers, water and fittings required with my system, leaving room for larger carrying space, and secondly, to the much smaller consumption of coal required to produce the same power." The figures I have given you, gentlemen, are, I believe, practically correct, and I will leave you to draw your own conclusions whether or not Mr. Howden's figures and Mr. Howden's statements do not require some correction.

Mr. J. I. THORNYCROFT. I was much struck with Mr. Howden's paper, but I am afraid the claims he makes are too extensive. I agree with Mr. Wright that the figures may require a little correction. The first thing that struck me on looking at the section of the boiler was that the furnace is very short. I think in that Mr. Howden gets an advantage, because the fire can be better attended to, and the boiler is evidently large in proportion to the coal burnt. Diagram No. 3 I would like to call attention to, because if, as is usually the case, a very considerable quantity of air goes through the fire, it is quite impossible that those rays of air going so kindly like rays of light straight to the fire could go in that way without being deflected; therefore, I think Mr. Howden must be a little mistaken in what takes place. Mr. Howden seems to be of opinion that that is the only way of burning coal well. Now, I think, the locomotive engineers have had some experience of burning coal well, and they do get a very good duty out of the boiler, but in this case they keep the fire-door open to some extent and they let in the cold air, but they deflect it down where they have plenty of depth and a high bridge, which causes the gases from the fire to meet the cold air; but unfortunately, I am sorry to say, in the locomotive boilers I have had the designing of, we have not been at liberty to put the locomotive fire-box down low enough, because we should have got down out of the bottom of the boat, but in the locomotive fire-box, where the fire-box is short and deep, the coal is tumbled in, forming a thick fire, and the air may be sent in at a very high velocity; there, I think, the combustion is very perfect, and I am not sure there is much to be desired. If the air can be heated as Mr. Howden proposes, there is no doubt heating the air is an advantage, but as to the fact that combustion would be so much more perfect, that I am not so sure about, because it is said, and I believe truly, that at very high temperatures the gases do not combine better, and you do arrive at a temperature when they no longer combine. In the boiler before us one thing that struck me was the very small opening that the air comes in at, but I do not know whether it is to scale. One thing I found necessary where really much coal has been burnt in the fire-grate was, to have the passages for the air so large as to use a moderate velocity and not to cut the ashes about into waves in the ashpits, which are liable to pile up and take fire; and if, in a rapid stream of air, you have the ashes under the bars take fire, I need not say what the result is. I think what Mr. Wright said as to the boiler only doing a low duty in this case, applies to the bulk of the boiler, which, of course, means per weight of boiler, for everybody's boiler would weigh about the same weight for the same pressure. Mr. Howden proposes reducing the boilers very greatly. There he will damage the result obtained. Now he has a large boiler to do the work; then he will have a small boiler to do the work, and then he must lessen the economy. The economy stated in the paper is very good, and I only hope, that when more diagrams are taken, it will be found that really so high a duty has been attained, because I take it to be a very great engineering success, if we can get engines to do the work with a little over a pound of coal. I must say something in favor of the closed stokehold, because it does really seem to be the simplest way of forcing the fires. It does not heat the air in the way Mr. Howden has stated, where he uses a special apparatus for heating, but I am not sure whether there is not something to be discounted off that, because any elaborate heating apparatus you put in the chimney to heat the air will be subject to considerable oxidation, and you will have to keep that in repair; then again, if you close your stokehold, all the air that comes in takes up the heat from the boilers round about and the temperature is more or less raised. Any heat that escapes from the boiler must be taken up by the air and it all goes into the furnace more or less, so I do not think the heating apparatus can be credited with so much advantage as he has given to it. I do not think the air is nearly so much heated in Mr. Howden's apparatus as he imagines. Mr. Howden describes the fire as a sort of Siemens' Gas Generator, as a large quantity of air is blown on the top, and he describes the combustion as being at the top of the fire and not underneath in the ordinary way. I am not sure whether that takes place or not. I am a little doubtful whether the combustion in these cases is very different to what it is in an ordinary fire.

Mr. A. F. YARROW. Mr. Sennett states that on the trial of the Mersey, 16.61 indicated horse-power was obtained per square foot of fire-grate, and 21.7 indicated horse-power per ton of boiler. He supplemented that statement by remarking that this was the best result that had come under his notice. I presume he refers to the boilers of large vessels.

Mr. SENNETT. Yes, ordinary marine boilers.

Mr. YARROW. For the sake of comparison, it may be interesting for me to state that a short time since we designed and successfully worked some boilers of very nearly the same power and heating surface as the Mersey boilers; if you refer to page 76 you will see each of the Mersey boilers had a heating surface of 1,950 square feet, and our boilers had each 2,000 feet of surface; it will be seen, therefore, that the heating surface of the two types of boilers was practically the same. Now, from our boilers we obtained 1,250 horse-power, with a weight of twenty tons, including water; giving 62.5 horse-power per ton of boiler. Now, referring to the grate area in the boilers of the torpedo boats which we are building for the British Government, we generally adopt 28 feet of grate surface; but in one, for the sake of experiment, we reduced it to 20, and, as a matter of fact, we did not find this reduction in area practically augmented the air pressure in the stokehold, nor, in fact, the steaming power of the boiler, but it gave greater ease to the stokers in managing the fires, on account of their reduced size. With the 20 feet of grate we got 650 horse-power—*i. e.*, we obtained 32½ horse-power per foot of grate, which also compares very favorably with what has been done in the Mersey. I simply mention these points for the sake of comparison, and do not for a moment wish you to suppose that I consider boilers such as I refer to would be equally applicable to those adopted in the Mersey, but it does show the great gap there exists between the most advanced practice in large vessels and that found in torpedo boat practice. I do submit that this gap could be reduced without practical objection. Now, as regards Mr. Howden's paper, on page 80 he gives us the comparison between two boilers, the new and the old, and he tells us of the gain he has obtained. It would have been of very great advantage to the Institution if he could have indicated—as there have been so many changes—how much of the gain was attributable to each change; perhaps the most interesting alteration, and the one to which he directs most attention, is the heating of the air; it would be most instructive if he could tell us what proportion of the gain is due to this cause alone. A very simple experiment could be tried to find this out, by letting the air, instead of passing through the heating apparatus, simply be drawn from the atmosphere direct, and brought into contact with the fuel in its cold state, comparing the result with that obtained if the air is first heated. I do not think that experiment would be an expensive or difficult one to carry out, and certainly it would be a very useful one. I certainly think the Institution would be further indebted to Mr. Howden if he would supplement his paper by giving us the result of such a trial; all the conditions in the two cases being precisely the same, the temperature of the air only excepted.

Mr. J. T. MILTON. I would like to make a few remarks, because my name has been mentioned in Mr. Howden's paper. In the first place, with regard to Mr. Wright's remarks, the question of forced draft as applied in the navy, and as it has been applied by Mr. Howden, are entirely different things. In the navy the attempt has been made to obtain a very high evaporative power from the boilers irrespective, or almost irrespective, of economy of fuel. In this case of the City of New York it has only been applied in order to obtain economy of fuel. The conditions are entirely different, and naturally, if you aim at different conditions, it appears to me that different means should be adopted for fulfilling those conditions. Now, in Mr. Howden's boiler, as Mr. Wright has pointed out, he has used a very large proportion of heating surface to grate-surface. That, I believe, is the right direction in which to proceed if you want to obtain economy. Mr. Wright has made some remarks comparing the boiler of the New York City with some of the navy boilers as to the amount of power got out of them in proportion to their size. There again the navy boilers and the merchant service boilers have different conditions to fulfill. In the navy, to obtain the power, they cannot afford to occupy the same space that can be given in the merchant service. So that in the merchant service they have very much larger boilers for the same power, worked with natural draft, the extra size being given for the purpose of facilitating cleaning, and keeping them in repair. If you look at this boiler it would strike any one who had been used to navy boilers that the spaces round here between the combustion chambers, and, in fact, the whole of the water spaces, were much larger than would be adopted if you were trying to get the same effective power in a smaller shell; in other words, the same effective power could be got in a smaller boiler than this if you chose to surrender accessibility for cleaning. Now, Mr. Howden, possibly rather generously, has left out reading what he remarks about my paper read at the last session. I stated then, and I believe now, that if you have to employ any heating surface in the funnel to abstract the heat from the waste gases, it is far better to abstract the heat by means of water than by means of air. If we want to cool an iron plate when it is made hot, we never think of putting a blast of air over it; we put it in water or sprinkle water upon it, because water abstracts heat very much more rapidly than air. With regard to the actual effect that Mr. Howden claims to have realized, I think he is mistaken in his estimate of the temperature of the air. I know there is nothing more difficult than to obtain the correct measure of the temperature of air. An ordinary thermometer does not show the temperature of the air in which it is placed, unless under very exceptional circumstances. It is affected by a radiation from all surrounding objects, and it shows practically the temperature of itself and nothing else. Now, in this case, I believe I am correct in saying * * * the thermometer for measuring the air temperature was placed between the outer and inner casings of the furnace door, and at the front end of the ash-pit. Is that so, Mr. Howden, in that space?

Mr. Howden. The air temperature from the air-heater is not taken at the furnace doors or casings, but in reservoir at place marked A on Fig. 1, Plate III, quite away from any influence of radiation. There are other holes for taking temperatures at the furnaces.

Mr. Milton. The chief engineer pointed out the hole in which they put the thermometer, and another hole in which they put another thermometer. In both those positions the thermometer would be exposed to the radiation of some very hot plates; these hot plates, in the first place, and all the underneath surface of the bars and ashes in the second place, and I think, therefore, that they can hardly be taken as showing the temperature of the air. As a matter of fact, I asked one of the men on board the question out of curiosity, whether this plate got hot, as it would do if the temperature of the air got to 300 or 400 degrees, and he said, No, you can always bear your hand on it. I do not know whether it is so. I think that Mr. Howden has been possibly led into error through the difficulty of measuring the air temperature. One point that has been raised prominently is, whether the system of a closed stokehold or closed ash pit is the preferable system for use. I think that this matter largely depends upon the number of boilers. If you have only one boiler, the closed ash-pit is, in my opinion, far simpler than the closed stokehold. With a closed stokehold you have a lot of bother with the doors and air locks, and so on, and it is a very simple matter with the closed ash-pit. With more boilers I do not like to say. When you have a great number of boilers in one stokehold, probably the other would be simpler, but when the air once gets in under the furnace bars, I think the effect is the same whether it comes in from the closed stokehold or from a closed ash-pit; the chemical effect of the air on the fire cannot be very different. I would like to hear Mr. Howden's testimony on one matter he has mentioned here, as to the probable continued efficiency of boilers worked by forced draft. I am acquainted with the results obtained by the boilers he was speaking of, and I think that, if anything, the description he has given of the trouble they gave is understated rather than overstated. Those boilers, as he said, were boilers fitted on something like a locomotive plan, and in them, because the fires had brick sides, and there was nothing to take away the heat of the products of combustion, the tube plates were subjected to a much greater temperature than they would have been in ordinary boilers, and therefore the effect on the tube plates is fairly comparable to that likely to be obtained with the higher temperatures occurring in furnaces with forced draft. The tubes could not possibly be kept tight when there was any sea-water used in the boilers at all, and they had to be supplied with absolutely fresh water the whole of their lifetime. It meant a very serious trouble. In this boiler, the City of New York's, having a small grate, and we will say a double proportion of furnace crown to extract the heat from the products of combustion before they reached the tube plates, that difficulty is met, and I have no doubt it is to a large extent to this abnormal proportion of furnace crown that the continued efficiency of the City of New York's boiler is now owing.

Mr. W. Boyd. * * * Mr. Howden makes a remark in his paper, which for my own information I should like by-and-bye if Mr. Sennett would answer, and that is, whether in war vessels on a foreign station, fitted with forced draft, this forced-draft system has been put in use after twelve months' work under ordinary natural draft, and what is found to be the effect of that change? From my experience and knowledge of the mercantile marine, I am strongly inclined to think that we must look to some form or another of a closed ash-pit in contradistinction to a closed stokehold. I believe it would be found to be simpler, and generally more acceptable, and, what is more important still (if a suitable application of this system can be found), to be cheaper. I think either the Ferrando system, which was alluded to by our president yesterday in his opening address, or some such arrangement as Mr. Howden's, will be the one that will be found hereafter to be most applicable for use in the mercantile marine; and speaking in relation to those two systems, it does seem to me that Mr. Howden, in his arrangement of dividing the air current and giving unequal power on one side of the bars to the other, is in the right direction, for this reason, that he thereby removes the place of the most rapid combustion from the neighborhood of the fire-bar to the neighborhood of the surface of the fuel. That seems to me to be an important point which Mr. Howden brings out in his paper, though perhaps other people may think differently. Then there is another point. Mr. Howden speaks in general terms throughout his paper about a moderate water-pressure under the bars and a greater pressure above the fire-bars. I looked in vain through his paper for any indication of what that water-pressure was. Speaking from recollection (and I was on board the New York City on her first voyage down the Clyde), I think it was from five-eighths to three-fourths of an inch, which is of course, comparatively speaking, very small indeed, but it is not mentioned, so far I can ascertain, in the paper, and perhaps Mr. Howden in his reply later on would indicate not only what is the pressure in the one, but what is the difference between the pressure under the bars and the pressure above the bars.

Mr. W. WATSON. The City of Dublin mail steamers between Kingstown and Holyhead have been referred to both by Mr. Sennett and Mr. Howden, so I am glad to have the opportunity, as being connected with that company, of saying a few words about what we have done in relation to artificial draft. In the year 1883 we were arranging to tender for a new contract for the mail service to the post-office, and we sent in two alternative tenders, one to improve our existing steamers, and the other to build much more powerful and larger vessels. The tender for improving the existing steamers was based on what Mr. Butler had shown could be done by artificial draft in the Satellite and the Conqueror, and I am glad to be able to say that the results we have obtained have fully borne out our anticipations of what would be effected by the use of it. The system we have adopted is exactly the same as Mr. Sennett has described in his paper "on closed stokeholds." Our engines formerly indicated about 3,000 horse-power. * * * We improved our boilers and made some alterations in the wheels of the vessels, to enable us to use more effectively the extra steam to be obtained by the use of artificial draft. The vessels are fitted with oscillating engines of a low-pressure jet-condensing type, and they indicated, previous to the alterations, an average of about 3,200 horse-power, and since we have applied this system of forced draft they now indicate from 3,800 to 4,000 horse power on the average. * * * We have worked with as much as 1½ or 2 inches [of water] with a proportionate increase of horse-power; but the object we had in applying the system was amply gained by the use of, say, on an average, one-half inch water-pressure. There are two points which have been referred to, which I am able, from the experience we have had, to say something upon. The first is a very important point, *i. e.*, what the effect of the use of these closed stokeholds has upon the ordinary working *quoad* the men. We find the greatest possible advantage is effected by it—the men are much more comfortable and prefer it in every way. This is especially true in bad weather, where formerly a great quantity of water would go down through the open deck gratings, and either the inconvenience of the water would have to be borne, or the gratings would have to be covered over with tarpaulins, and the men would have to suffer the inconvenience of want of sufficient air. In the present state of things we are quite as well off in the worst weather as we are in the finest. The second point is even more important, and is, what is the effect upon our boilers of the artificial draft? We cannot find that any detrimental action is to be traced to the new system. The boilers appear to be standing quite as well and giving as little trouble in maintenance as the former boilers did with natural draft since the application of artificial draft to our existing vessels.

* * * * * * *

Mr. F. C. MARSHALL. I stand in a position somewhere between the two parties represented in this discussion, having had, perhaps, more experience than most people in forced draft of the one sort so ably set forth by Mr. Sennett, and having to do with commercial work, on the other hand, to which Mr. Howden calls attention, and I am sure I speak the sentiments of all present, when I give expression to the deep sense of indebtedness that I feel, and I believe we all feel, towards Mr. Sennett and the officials of the Admiralty, for the very complete—I may say perfect—paper they have given us as to the result of the working of a great many of the vessels of the Royal Navy under forced draft, with closed stokeholds. We also are under great obligation to Mr. Howden for having brought this matter forward so far as he has done. He has done it at a great expense and sacrifice to himself; and I think we may say, whether we think it a great advance or not, or whatever we may think of it in relation to what has been done in the navy, it certainly is, so far as the commercial marine is concerned, a step in advance. I think we may fairly say, as Mr. Boyd has already said, that between the two systems of Ferrando and Mr. Howden we may get certainly a very admirable under-grate system; and, under other circumstances, perhaps the closed-stokehold system will be the best. So far as the economical results are concerned in the two systems, it has fallen to my lot to carry out some experiments on both systems. I have been making recently a large number of boilers for the Italian navy, of the locomotive type, to work at 120 pounds pressure, and as they have to develop a very high power, I was anxious to ascertain whether these boilers would really develop the power before they were sent out to Italy. I fitted a closed stokehold to two of them in the works, and placed them in the same positions, and as nearly as practicable the same conditions, as they would be when on board ship; arrangements were made whereby the water evaporated and coal consumed, the air pressures and quantity passing through the fans, the temperatures of escaping gases, and other particulars recorded in the table subjoined could be carefully ascertained and noted. The experiments were made with the object of ascertaining the maximum evaporation obtainable under moderate forced draft pressures, such as would be readily available under ordinary conditions at sea, for the class of vessel for which the boilers are intended, viz., torpedo cruisers. In these experiments I was anxious to ascertain also the respective merits of two kinds of fire-bars. The results were the following:

Summary results of evaporative tests with two boilers of a modified locomotive form.

Number of trial.	Date.	Duration of trial.	Surfaces.		Mean steam pressure.	Water.		Water evaporated from and at 212 degrees.				Coals.		
			Heating.	Grate.		Total pounds.	Per hour.	Per hour.	Per pound of coal.	Per square foot of grate.	Per square foot of heating surface.	Total pounds.	Per hour.	Per square foot of grate.
		h. m.					*Lbs.*							
1	Mar. 4.	1 32	2, 232	52. 5	125. 5	44, 969	29, 336	35, 937	6. 969	685	16. 1	7, 907	5, 165	98. 3
2	Mar. 13	1 23	2, 232	52. 5	125	44, 004	31, 809	38, 998	6. 889	742. 8	17. 47	7, 840	5, 667	107. 9
3	Mar. 16.	1 13	2, 232	52. 5	123	41, 816	34, 369	41, 999	6. 62	799. 9	18. 81	7, 720	6, 344	120. 8
4	Mar. 18.	1 5	2, 232	52. 5	120	36, 264	33, 474	40, 905	6. 566	779. 1	18. 32	6, 720	6, 203	118. 1
5	Mar. 20.	1 41	2, 232	52. 5	116. 2	54, 900	32, 613	39, 821	8. 566	758. 5	17. 84	7, 826	4, 648. 8	88. 5

Number of trial.	Air pressure.			Revolutions of fans.		Temperature.				Class of coals.	Remarks.
	In stokehold.	In ash-pit.	In uptake.	Port.	Starboard.	Stokehold.	Uptake.	Atmosphere.	Feed.		
1	3. 54	3. 13	0. 65	1, 283	1, 150	75	1, 150	44	37	Cowpen Coal Company's ordinary best steam coals, not hand-picked, and rather damp and small.	Ordinary fire-bars, $\frac{5}{8}$ inch thick, $\frac{1}{2}$-inch air spaces, no opening through fire-doors. Both fans discharging into stokehold.
2	3. 605	3. 446	0. 25	877	909	66	1, 163	37	36	Cowpen Coal Company's ordinary best, as above.	Thin fire-bars, $\frac{3}{8}$ inch thick, $\frac{1}{8}$-inch air spaces, no opening through fire-doors, fires thinner. Both fans discharging into stokehold.

Summary results of evaporative tests, &c.—Continued.

Number of trial.	Air pressure.			Revolutions of fans.		Temperature.				Class of coals.	Remarks.
	In stokehold.	In ash-pit.	In uptake.	Port.	Starboard.	Stokehold.	Uptake.	Atmosphere.	Feed.		
3	4. 955	4. 955	0. 91	1, 244	1, 208	66	1, 159	38	40	Cowpen Coal Company's ordinary best, as above.	Fire-bars same as No. 2. Both fans on to stokehold, one boiler steaming. Results calculated for two boilers.
4	3. 07	3. 36	0. 633	925	1, 171	77. 5	1, 210	40	39	Cowpen Coal Company's ordinary best, as above.	Fire-bars same as No. 2. One fan on to ash-pit, other to stokehold. Air getting into fire doors, one boiler steaming. Results calculated for two boilers.
5	2. 0	3. 706	0. 812	769. 2	1, 212	87. 6	1, 200	50	40	Nixon Navigation, new, dry, and good.	Fire-bars same as No. 2. One fan on to ash-pit, other to stokehold. No air got through fire-doors, one boiler steaming. Results calculated for two boilers.

In test No. 1, ordinary fire-bars were used, ⅝ inch thick, ½-inch air spaces between the bars, being placed as usual longitudinally in the furnace.

In tests Nos. 2, 3, 4 and 5 thin fire-bars were used, ⅜ inch thick, and barely ⅛-inch air space between. The bars were placed across the furnace.

In tests Nos. 1, 2, and 3 both fans discharged as usual into the stokehold, but in No. 3 one boiler only was under steam, both fans being used for this boiler.

In Nos. 4 and 5 one fan discharged direct by means of a casing into the ash-pit, while the other discharged into the stokehold, so as to prevent the flame from issuing from the fire-door when fresh coal was being supplied.

With the ordinary fire-bars used in test No. 1 a water trough was required in the ash-pit, as the heat was intense.

With the thin fire-bars used in the other tests the ash-pit was quite cool, and the edges of these bars, after thirty hours' steaming, were quite sharp as from the mold.

In the first instance, the boilers were worked under the closed stokehold system; the fire-bars used were of the ordinary description, placed longitudinally to the direction of the draft, as is usually done; they were of wrought iron, five-eighths to three-quarters inch wide, with air-spaces about half-inch. After a series of experiments these bars were removed and the furnaces fitted with what, for the sake of distinction, we will call the Ferrando fire-bar, but which is really only an extremely thin bar of cast-iron about 8 millimetres wide at top, and 4 millimetres thick at bottom, 3 inches deep, placed in short lengths *transversely* to the direction of the draft, as closely together as the roughness of the castings will admit, leaving spaces of from 2 to 3 millimetres in width for the air to be forced through, as will be noticed, in very finely divided streams, and, from the thinness of the bars, bringing it into intimate contact with the fuel on the bars. Our temporary stokehold was fitted with two 3 feet Brotherhood fans. In the first set of trials—with ordinary fire-bars, as also the first of those with the Ferrando bars—both fans discharged their air into the closed stokehold in the ordinary way, and both boilers were worked. In the second set of trials with Ferrando bars, one boiler only was used, and one fan connected directly by a channel to the ash-pit of that boiler, while the other supplied air to the stokehold, in order to maintain a pressure in it, to prevent the flashing back of the flame at the fire-door. (The results of the working of this boiler are doubled, so as to compare with the other trials.) The accurate results of these trials are given in the preceding table, but they may be roughly stated as follows: The mean weight of water evaporated with the ordinary bars under closed stokehold conditions may be taken at 35,000 pounds, the pressure of air being 3¼ inches, the coals burnt per square foot of grate 98.3 pounds. The Ferrando bars, under the same closed stokehold conditions, gave 38,998 pounds of water, with an air pressure of 3½ inches, and a consumption on the grate of 107.9 pounds. Then we come to the same Ferrando bars with the under-grate system—that is, the fan connected directly to the ash-pit—a pressure being maintained in the stokehold only to prevent flame flashing back through fire-door owing to pressure in furnace, which gives in one experiment 40,905 pounds of water for 3.36 inches air pressure under the grate, and 3.07 inches in the stokehold, the coal burnt being 118.1 pounds per square foot of grate; and in the next experiment 39,821, or say 40,000 pounds of water with 3.7 inches pressure in the ash-pit and 2 inches in the stokehold—the coal burnt being 88.5 pounds of hand-picked Nixon's navigation coal in this case, as against the best unscreened Cowpen coal in the former cases. The last named circumstance, which arose from inadvertence, renders the comparison not quite so complete as we could wish, so we must leave it practically out of the question, excepting that it gives us an idea of the fire grate, fire and tube resistance, which may be taken at the difference between the ash-pit and stokehold pressures, because the latter was regulated until it just overcame the tendency of the flame to rush out at the open fire-door; in this respect it is valuable, otherwise it must be thrown out. It will thus be seen that in the two previous experiments, allowing for errors in observation and the differences in pressure, the two systems gave in practical efficiency nearly the same results, and that the water evaporated follows the relative pressure of air used. * * * I am disposed to give some value to Mr. Howden's view with reference to the injury done by the inrush of cold air on the opening of the fire-doors in the closed stokehold system. I am quite aware of what Mr. Sennett will say, and I know what my own experience is, that we do not suffer in our boilers, so far as our experience goes, from the opening of the fire-doors. So far, we have had no difficulty with our tubes. The system has been applied principally to boilers of the long description having the long flame box in which the air gets heated before it comes in contact with the surface of the plates against which it may come. I quite agree with Mr. Boyd, the time has come when this question has to be faced by the commercial marine, and it is a question as to which of the two systems will be the one to be adopted. I think a great deal is to be said for Mr. Milton's view, that to some extent it will depend on circumstances; where you have one or two boilers at the utmost, probably the ashpit system will be adopted, that is with shallow ships, with greater advantages and facilities than the closed stokehold. My own feeling is, I think, seeing that the effect is very much the same in both cases, the tendency would be to go to the closed ash-pit, and leave all free above as at present, notwithstanding the advantage which our friend from the City of Dublin Steam Packet Company mentioned with regard to bad weather. * * * With reference to the Ferrando system with the close bars, which so far as I know, is a novelty in this country, I will tell you this fact, that in the harbor of Genoa I saw a vessel with engines indicating something like 3,000 horse-power being coaled from a Newcastle ship with duff coal—that is, this very large passenger steamer running from Genoa to Calcutta was being coaled with coal hitherto treated as refuse and worth about half ordinary bunker coal. That is a very important fact. I happened to be in Genoa when that vessel returned; the coals had cost for her voyage scarcely more than one-half what the other coal would have done. The result, so far as consumption and the maintenance of steam was concerned, had been admirable—nothing could be better. There was a slight saving in the quantity of fuel per day, and the speed of the vessel had been maintained much more uniformly during the whole voyage. This is a great fact, and a great fact in the face of the present condition of things. If we can, by using extremely thin bars placed close together, and using a forced draft, burn coal of one-half the value, then I say we are doing a very great service to the mercantile marine, and we give due honor and credit to our friends, even if they are not countrymen of our own, but to the people of Italy, who have introduced that system. Another steamer which had usually run at something like 9 knots now goes about 9¾ to 10 knots steadily, on a consumption of 2 tons per day less than she had been burning of ordinary coal, on duff coal from Newcastle. So it seems to me there is something to be learned in reference to the use of thin bars as well as whether apart from, or in conjunction with forced draft.

Mr. W. PARKER. Every one, I think, will agree that, as regards the mercantile marine, any further reduction in the consumption of fuel in our steamships must be looked for, as Mr. Boyd has indicated, in the making of the steam and not in the manner in which the steam is used. Of course everybody here knows that at present we have got almost to the end of our tether in the upward range of pressures with the present form of boiler, and we have also an engine capable of utilizing that pressure and giving us the full advantage of it. Therefore if we look for further decreased consumption we must look in the direction indicated by these papers, and, as I said before, any information in this direction which can throw light on the subject cannot fail to be most valuable. I think Mr. Howden seems a little too sanguine as to the results he obtains from this process of his. As I remarked on the last occasion when he read a paper here, it cannot be held that simply because he reduces the grate surface of a boiler he also decreases the other proportions of the boiler in the same ratio. I visited the steamer New York City for the purpose of satisfying myself what that ship was really doing. There is no doubt that Mr. Howden has settled one point, and that is that it is quite practicable to burn from 35 to 50 pounds of coal per square foot of grate in a steamer engaged in a long ocean voyage without any damage whatever to the interior or exterior of the boiler. The performance of the New York City has placed that beyond dispute. I find she has been running for about eighteen months, and running under rather unfavorable conditions; for every one will admit that the man who is in charge has a great deal to do with the success or non-success of the machinery or apparatus. It has been the misfortune of the manager to have had three different engineers on that ship, and the last voyage that she made she had a fresh engineer, and she did better work on that voyage than she did before, and not only had she a fresh engineer, but every one of the firemen was new to the ship. Mr. Boyd inquired with regard to the pressure of air that was used in the ship, and the information that I have from the engineer who worked the vessel is that in the stokehold they have an air pressure of about 1¼ inches, but in the grate over the fire they have not more than a quarter of an inch of air pressure. It ranged during the last voyage from one-quarter to five-eighths from here to Demerara, and that is not an excessive air pressure; taking the indicated horse-power at the moderate amount of 600 and the consumption at 9 tons of coal a day, it gives some 24 pounds of coal per foot of grate, and that again is not excessive. But the engineers explained that they took an hour to clean a fire instead of a quarter of an hour or twenty minutes, and the other two furnaces, by means of a little more air pressure, would keep the boat steaming at the same rate of speed. If that were the case, and they were doing the work with two furnaces instead of three, they would be burning about 56 pounds of coal per foot of grate. As Mr. Milton truly said, it does not follow because the grate surface is reduced that the whole boiler would be reduced, and that, because the City of New York was running with half the grate surface that she had, the Oregon could run with boilers half the size of those with which she was running. * * * I will make one remark with regard to the rush of cold air. Mr. Howden gives us something there worth consideration. In the navy the trials hitherto have only been for six or seven hours, and they have not had much trouble. But in a steamer that is engaged to steam from thirty to forty days without stopping it is a matter of very great importance. For instance, I have in mind a steamer that has done well until her last voyage—and she is now on her tenth voyage round the world—has in fact never had a mishap; but on the last voyage she had to steam from Australia round Cape Horn to London, a thing which would not under ordinary circumstances be attempted by a steamer of that class. In consequence of bad weather she had to be driven at the top of her speed and had to steam with bully coal taken from Australia. This bully coal has about 50 per cent. of ash in it. It is of such a dirty nature that the fires require to be cleaned twice as often as with the ordinary coal. The consequence was that these doors had to be opened and the fires cleaned every watch; there were twelve furnaces in the ship and they had to be cleaned every watch. When that ship arrived in this country we were very much astonished to find her furnaces had collapsed, but when we came to inquire into the matter and ascertained the cause of the collapse we were not so much surprised. The cold air coming down that stokehold and rushing down those furnaces caused a creeping to take place in the furnaces, and at each creep there was thrown off a scale, till a large accumulation of scale took place, and the end of it was that the furnaces became hot and the pressure crushed them in. The idea I formed was confirmed by the fact that each furnace that collapsed was directly under the ventilator. Of course they had always been under the ventilator before, but they had not been opened so frequently, and the inrush of air was only half on the previous voyages, but on this voyage it was so excessive that the cold air caused the contraction which Mr. Howden has spoken about which is so detrimental to boilers.

Mr. R. Sennett. Mr. Wright compared the dimensions of the boiler of the New York City with those of boilers working with natural draft and in closed stokeholds, and showed that the boiler in that ship was not, strictly speaking, worked with a forced-draft system. Mr. Milton called attention to that and said that in the mercantile marine and in the Royal Navy we were necessarily working in opposite directions; that in the mercantile marine the great object was to secure economy of fuel without reference to the capacity and weight of the boiler, whereas in the Royal Navy the principal object was to gain power with reduced weight of boilers without so much reference to economy of fuel. Mr. Howden does not seem to take quite the same view as Mr. Milton does. I take it the main object of his paper is to prove that if his system had been applied to the Oregon, instead of nine boilers of a certain size the same power might have been developed by six boilers of a considerably smaller size. I think this shows that Mr. Howden himself believes that his system would be attended with a reduction of weight and space required for the boilers. But, taking the New York City as a basis for argument, I find the six boilers that Mr. Howden proposes to put in the Oregon would be equal to rather less than 8,000 horse-power, instead of the 12,000 I. H. P. stated. Mr. Boyd asked if any of the war vessels fitted with closed stokeholds have been employed on foreign stations. Not many of them have as yet, but the Satellite, referred to by Mr. Butler in his paper three years ago, has just completed one commission in the Pacific and is now going to be recommissioned in China, and, so far as we know, everything has been perfectly satisfactory. The officers of the ship have had no restriction placed on them as regards the use of the fans and forced draft. There are also several other vessels that have been away for many months. In accordance with the Admiralty regulations full-power trials have to be made at least twice a year, and so far we have had no complaint whatever as to any injurious effect on the boilers by working the fans. I do not think that I need say much about the question of the cooling effect of the air on the boiler. That is a circumstance that must occur with all boilers, except, perhaps, those with closed ash-pits. Nearly all steamships at the present time are fitted with ordinary boilers, and when the fire-doors are opened air must get in over the fires, but we find, as a matter of actual experience, that the boilers do not suffer in the serious manner stated, except in very exceptional cases. The case quoted by Mr. Parker occurred under very exceptional circumstances.

Mr. Parker. May I offer a word of explanation to set that right? It is a fact that as to the Allan steamers, trading between Liverpool and Quebec, instructions based upon the experience of the engineer-in-chief have been issued, to the effect that when they arrive at the other side in winter time they must, under no consideration, open the furnace doors, but allow the fires to burn out, because it was found if they did open the doors, that the cold air would rush into the furnace and give them a great deal of trouble.

Mr. A. C. Kirk. Might I be allowed to explain that where the scale fell down thickly in these boilers was off the bottom of the corrugations.

Mr. Sennett. All I wish to explain is, that this question of the cold air getting into the furnaces exists with regard to nearly every boiler, and is not peculiar to the closed stokehold system. In my opinion the evil effects supposed to be produced by air entering the furnace through the open fire-door are much exaggerated, and as a rule they exist more in imagination than in actual practice. Mr. Henwood asked a question about the evaporation of one pound of fuel with forced and natural draft. I am unable to give him information on this point, as we have made no special evaporative experiments. I think I have nothing more to say, except to thank you for the kind way in which you have received my paper.

Mr. J. Howden. * * * There have been some remarks made regarding the comparative power, taken from the boiler of the New York City, viewed in relation to its size. As I explained in my paper, I had to design this boiler to work, not only by forced combustion, but by natural draft also, and I had to sacrifice a good many advantages which I could have secured had the boiler been made for forced combustion only. The diameter of the boiler, as I have already pointed out, could have been reduced considerably without affecting the heating surface, but as there was abundance of room for the boiler, it was made large and with very wide water spaces, as the plans show. I could also have reduced the size of tube considerably and have had more effective heating power with forced draft, with less surface. It is, therefore, quite out of place to compare this boiler of the New York City, on the basis of its capacity, as Mr. Wright has done, with those boilers of the Navy, where with a large grate surface and irrespective of fuel, a large power was forced out of them for a few hours under the closed stokehold system. If Mr. Wright had given the quantity of coal used to produce the respective horse-powers, then a proper comparison could have been made. As I have said in my paper, economy in fuel is the foundation of my system, and it has been with the object to insure economy that I have adopted the proportions which exist in this boiler. It was not required to produce a very high power in this boiler, and, therefore, I used a grate proportioned to the power wanted with easy working at sea. For mercantile steamers, take the example of the Oregon, given in my paper, for reduction in size of boilers on my system to produce an equal power. I there show 6 smaller boilers, substituted for 9 larger ones; 36 furnaces for 72, and an aggregate fire-grate of 641 square feet for 1512. This was considered an impossible reduction when I read my paper on the subject in 1884, but I have shown that I have accomplished, proportionately, more than this in the New York City, in ordinary work at sea without any exertion whatever. This being so, it is clear that I could reduce the boilers considerably more in proportion than I have proposed in regard to the Oregon. You have heard how that with two furnaces only and 24 square feet of grate the New York City has, when tried, not only been able to drive the engines at 630 I. H. P., but also at the same time to raise the steam from 80 to 85 pounds pressure and blow off at the safety valves. If the latent power in a system of combustion that can accomplish such a feat be considered for a moment, there will be a very different conclusion arrived at than that which has suggested the question whether or not this is a forced-draft system. What I say in reply to this is, that there is no forced-draft system, closed stokehold, or any other that could dare attempt at sea such a production of power per square foot of grate with salt water in the boilers, for as I have mentioned the New York City has virtually been worked with salt water only ever since she left the Clyde on 13th October, 1884. There have been questions asked by some speakers as to the air pressure used in the furnaces of the New York City. I cannot tell, of course, very well what pressures may be used by those on board when at sea; but I may mention the pressures that should be worked at, to produce about 20 I. H. P. per square foot of fire grate in such a boiler as that of the New York City. With the fire-bars as presently used in that steamer, about three-eighths of an inch of water pressure would be required under the fire bars, and with a proper area and size of holes in the air-distributing boxes above the fuel, about 1 inch water pressure there. As I have endeavored to explain, the difference of increasing the velocity of the air entering above the furnace, say from 20 to 50 feet per second, which I can do quite easily by means of the regulating valves, is very marked on the power of the furnace. The force at which the air strikes the fuel is as the square of the velocity, so that at the highest velocity the force is as 25 to 4 of the less velocity. By this means, therefore, I can perform a rate of combustion quite unattainable by other conditions, as a much reduced weight of air entering above has an equal or greater effect in producing perfect combustion, while as it scarcely adds to the pressure of air in the furnace above the fuel, it does not hinder the passage of the greater amount of air at the lower pressure from below ascending through the fuel and producing a high rate of combustion. It is by the balance of these differential pressures of air above and below the fuel that the power and economy of these furnaces on my system are produced. By the regulation of these, almost any power can be produced at pleasure. There have been a great many points referred to in the discussion which I would have wished to notice had time permitted, but there is only one which I will now detain you with. It is that of the closed ash-pit system which has been referred to by some speakers to-night as the "Ferrando" system. That is exactly the system I tried in 1862 and which I described in my paper of 1884. I worked that system all round with different pressures under the grate-bars, and as I have described, whenever I increased the combustion above natural draft rates the troubles increased in all directions. It is not a system fitted for a high combustion if economy and workability are desired. The manner of working described by Mr. Marshall, with thin fire-bars, as used by Mr. Ferrando, as I understand him, is a combination of the closed stokehold and the closed ash-pit systems, one fan, as mentioned, blowing into the ashpit of the boiler in which the experiments were tried, and the other fan into the closed stokehold built round the boiler, giving air and maintaining pressure above the bars. By this means, which is after the manner of my system in effect, I have no doubt a high combustion will be attained.

Since the preceding papers were read, a number of British naval vessels have been tried, all fitted with the system of forced draft described in Mr. Sennett's paper, and giving about the same result in I. H. P. per square foot of grate as the vessels therein mentioned. The forced draft trials of the Archer class go far towards sustaining the objections raised by Mr. Howden against the closed stokehold system. The trials of the Archer, Brisk, and Cossack had to be discontinued on several occasions, owing to leakage of the boiler tubes; and when it is remembered that these trials are for only four hours, and that no provision is made for hoisting ashes, it becomes a question of serious consideration whether the maintenance of this high power for such a short period brings with it advantages at all comparable with the continued develop-

Bureau of Steam Engineering's System.

Plate IV.

Fig. 1.

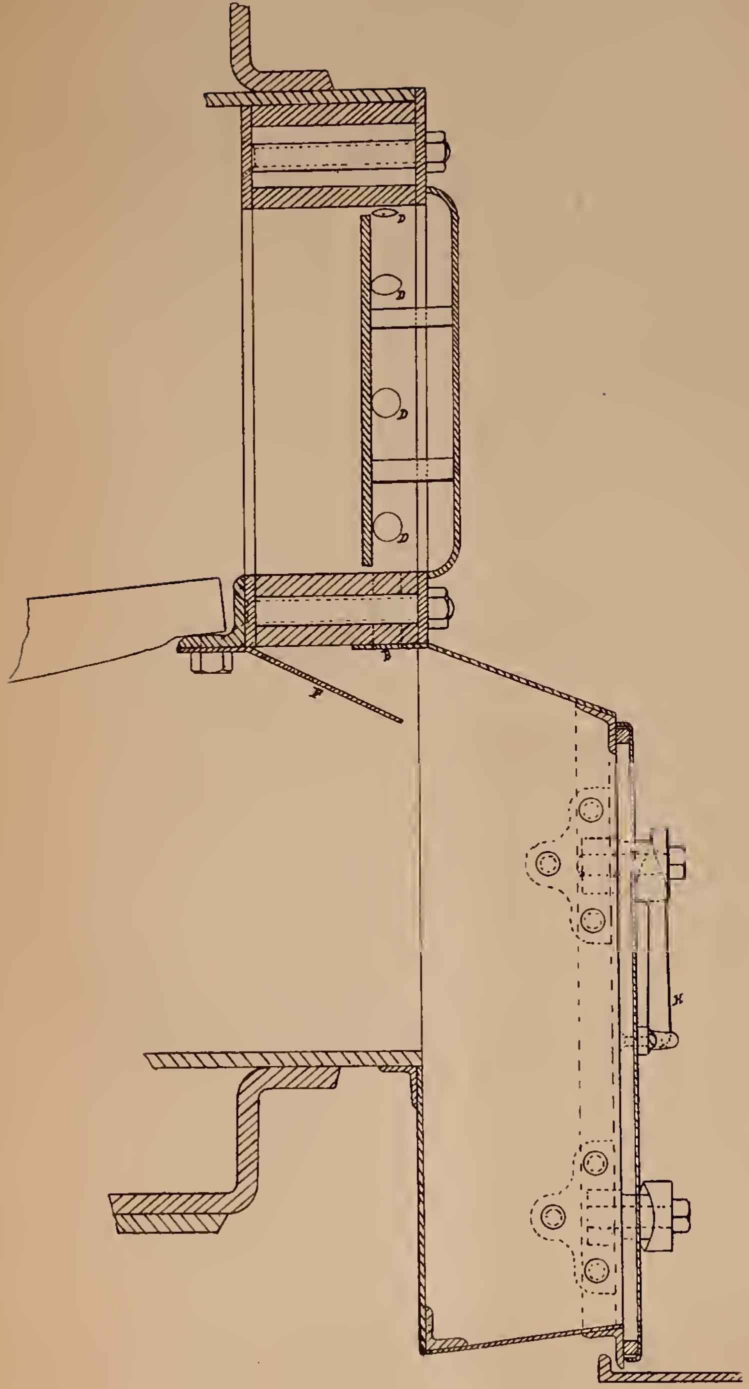
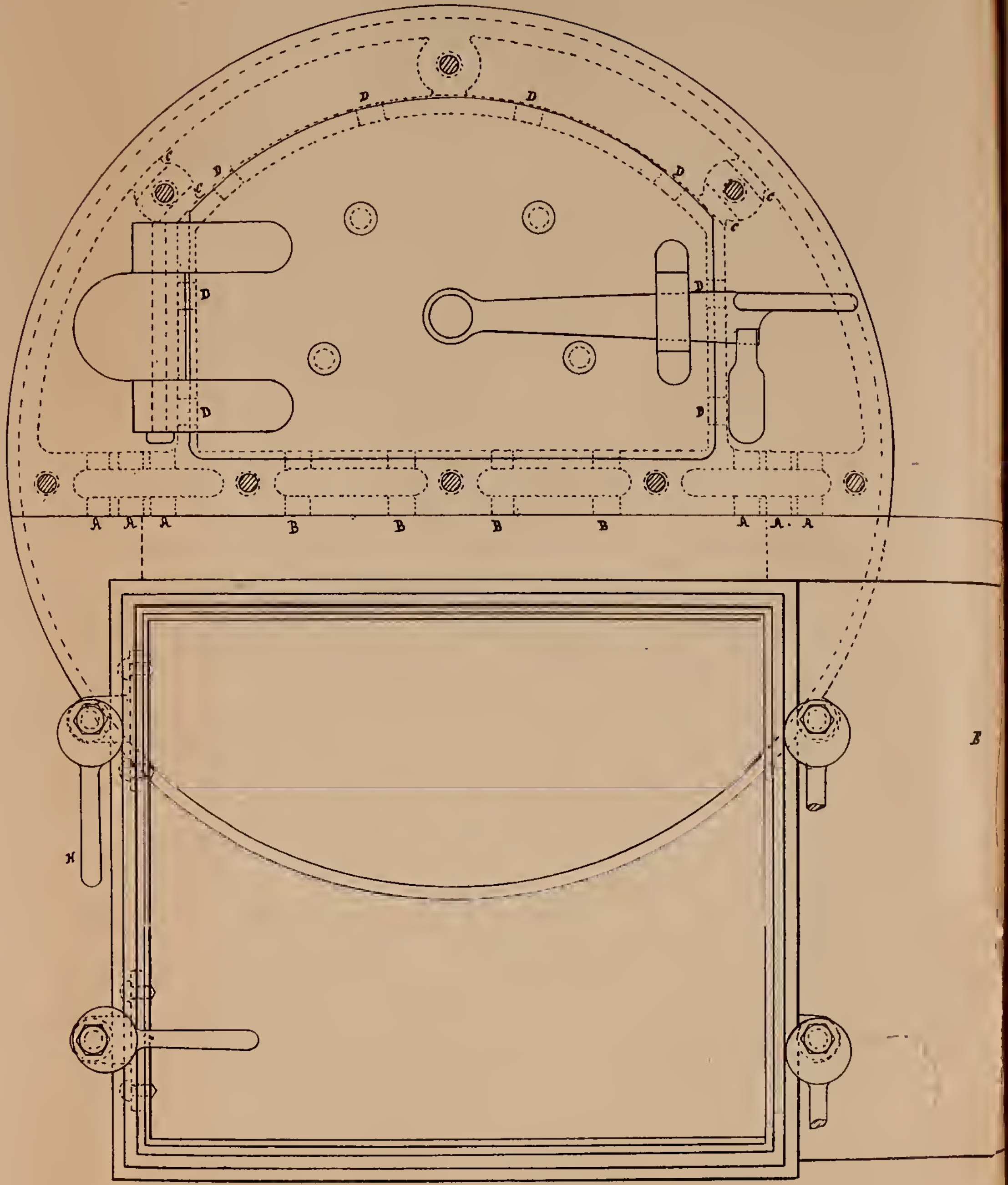


Fig. 2



ment of a reasonably high power with an economical expenditure of coal, such as is possible with the closed ash-pit system.

A number of steamers have been fitted with Howden's system during the past year, amongst others the Celtic of the White Star Line, and the Ohio of the International Navigation Company. One of the latest steamers fitted with this system is the City of Venice, whose engines were converted from compound to quadruple-expansion. Her boilers were designed to develop 1,800 I. H. P. with 80 square feet of grate, but on trial she could only work off 1,300 I. H. P., owing to some derangement of the valves; she was afterwards tried with half the grate surface in use, when it was demonstrated that there would be no difficulty in developing the power so far as the boilers were concerned. Unfortunately no data as to weight of boilers, space, or heating surface are obtainable.

BUREAU OF STEAM ENGINEERING'S SYSTEM.

In 1886, the Alliance was supplied with new boilers fitted with a system of forced draft designed by the Bureau of Steam Engineering, the arrangement of which is shown on Plate IV, Figs. 1 and 2. It was originally the intention of the Department to put six boilers in this vessel, as in the Enterprise and Nipsic, but with the introduction of the forced draft system, which was purely experimental, this number was reduced to four, having a total grate surface of 128 square feet. The boilers were designed to burn anthracite coal with natural draft, and were, of course, unsuited to the requirements of forced draft, the ratio of heating to grate surface being only 25.6 to 1, and the water surface and steam space being small. The maximum I. H. P. developed on trial was 1,022, but any attempt to run at this or at increased power for any length of time was attended with so much priming in the boilers that the trial had to be discontinued. Alterations were made in the boilers to prevent the priming, but no continuous trial was had previously to the sailing of the Alliance. The results obtained on a measured base were, however, sufficient to demonstrate the practicability of the system, and to show that a higher power could be maintained with the four boilers at forced draft than with the original eight boilers at natural draft.

The practical working of the system at sea presents no difficulty, as a recent run of the Alliance has demonstrated. On a continuous run of ten hours, using only two boilers with 60 square feet of grate (the grate surface of each boiler having been reduced to 30), the mean I. H. P. was 668, and the maximum 744, being, respectively, 11.1 and 12.4 I. H. P. per square foot of grate. There was an entire absence of priming, and no difficulty was experienced in operating the forced draft apparatus, the length of the trial having been determined by the arrival of the vessel in port. The coal burned was Welsh, of fair quality, the consumption being 29.9 pounds per square foot of grate.

The efficiency of the system may be judged by the results obtained from an experimental boiler at the Washington navy-yard, and which were published in the Proceedings of the Naval Institute, Vol. XII, No. 4, page 639. The boiler was of the "marine locomotive" type, and had a ratio of heating to grate surface of 32.73 to 1, with a water space of 245, and a steam space of 163 cubic feet. The coal burned was ordinary Cumberland Valley bituminous, and the evaporation when burning as much as 40 pounds per square foot of grate was 6.61, while with 37.5 it was 7.24, and this with a moderate air pressure—1.5 inches in ash-pit, and 1 inch in furnace door.

The air, which is drawn by the fan-blowers from the heated portion of the fire-room, is forced through the passage *E* into the ash-pit and furnace. The plate *F* is intended to direct a portion of the current of air through the holes in the furnace frame. There is a double row of holes at *A* and holes at *C*, so that the greater portion of the air which enters the furnace passes around the frame, and through the holes *D*, to the space between the furnace door and lining, whence it goes to the furnace through the space between the lining and furnace frame. There is a damper in *E* for shutting off the supply of air when firing or hauling ashes.

An arrangement similar to this is now being fitted to the new boilers for the Swatara, the number of which has been reduced from eight to six.

WYLLIE AND MORISON'S SYSTEM.

This system, which has been successfully applied in the merchant service, and which is now being introduced into some large steamers, is shown on Plate V, Figs. 1, 2, and 3. Like Howden's, it is on the closed ash-pit principle, the air supplied being drawn from a casing inclosing the smoke-pipe and front connections, and also from the smoke-pipe hatch through the hollow axis of a damper in the smoke-pipe.

Referring to the figures on Plate V, *h* represents the air-passage, *a* the door for shutting off the supply, *b* the furnace door, *d* the ash-pit door, and *c* the valve for shutting off the supply of air to the ash-pit. It will be observed that the doors open towards the boiler, that *a* and *b*, and *c* and *d* are connected by means of the pinions *p*, so that the movement of *a* or *c* is accompanied by a corresponding movement of *b* or *d*, and that the pressure of air tends to keep the furnace and ash-pit doors tight. With this short description, the figures are probably self explanatory. The patents cover a number of modifications of the arrangement shown, but the cuts show all that is peculiar to the system.

It is now in use on board the British steamers African of 1,086 I. H. P., Athenian of 4606, Chelydra of 1,400, Spartan of 4,088, and Stella of 932, and is being introduced into a number of others, from which fact it may be safe to assume that its working is attended with economy. As in the case of the steamers fitted with Howden's system, the boiler

Wyllie & Morison's System.

Fig. 1

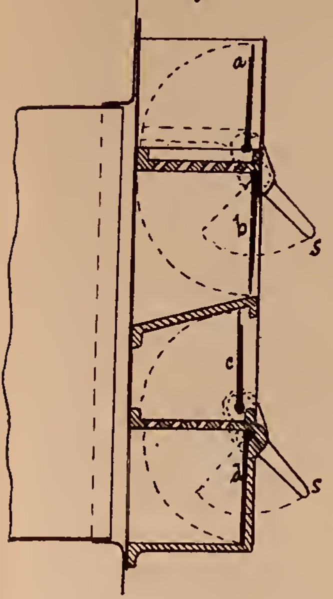


Fig. 2

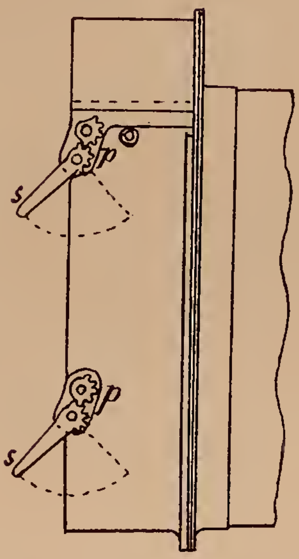
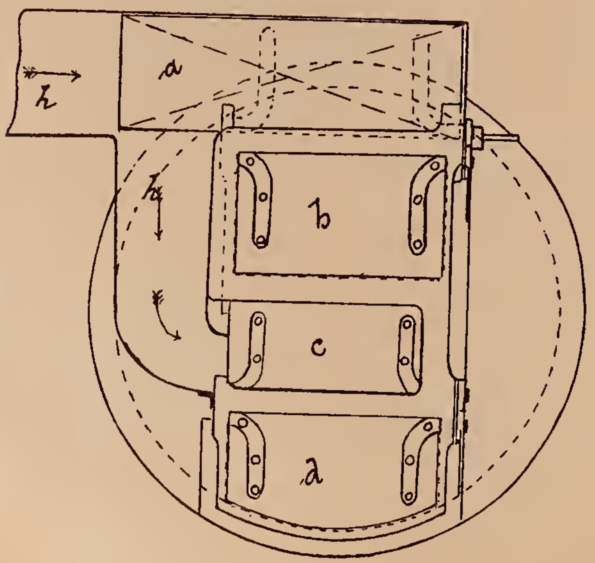


Fig. 3



Schichau's System

Fig. 4

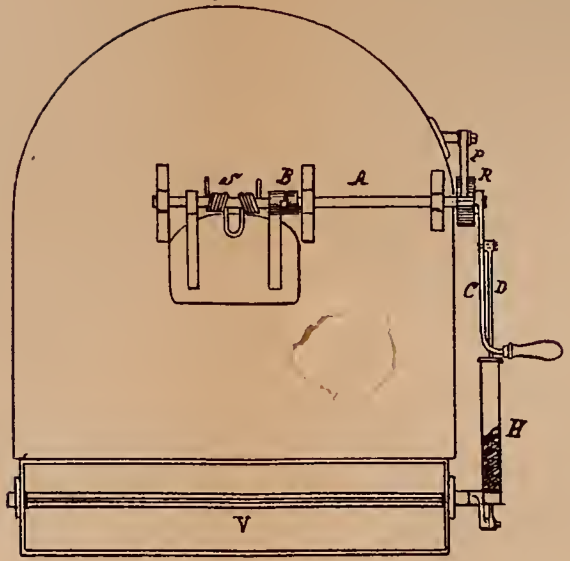


Fig. 5

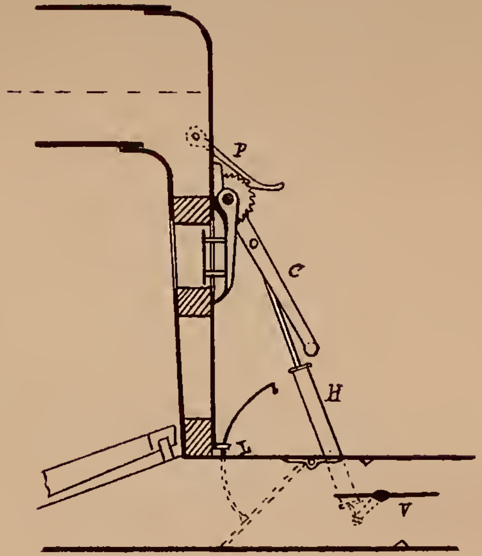


Fig. 6

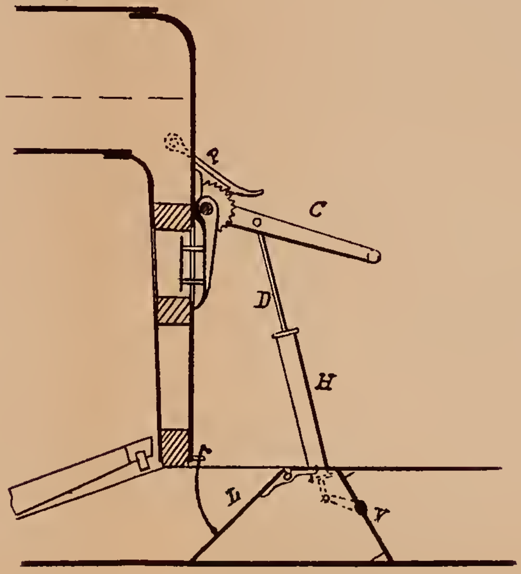
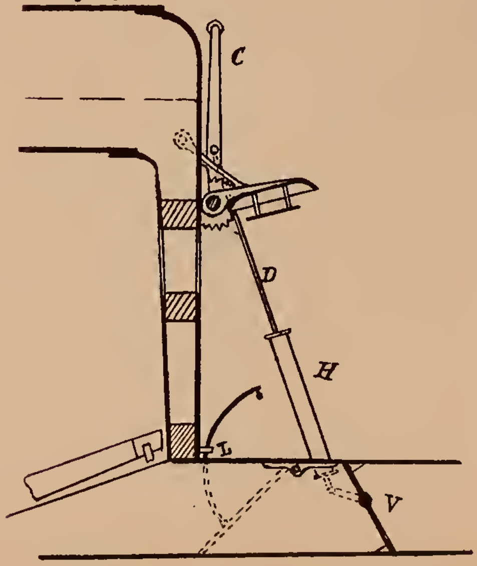


Fig. 7



data of the above steamers are meagre, but it may be safely assumed that the ratio of heating to grate surface is large.

SCHICHAU'S SYSTEM.

Figures 4, 5, 6, and 7, on Plate V, show the arrangement which has been applied with so much success in the Schichau torpedo boats. As will be seen, it is wholly an ash-pit draft, and the arrangement of the air-passage under the floor plates is only one of the plans adopted. *A* is a rod passing along the furnace front and carrying the hinges of the furnace door, one of which has a shoulder on it at *B*, which, when the lever *C* is turned beyond a certain point, comes in contact with a corresponding projection on the rod *A*. To a point on the lever *C* is attached the rod *D*, which carries a case containing the spring *H*, and operates the air-valve *V*. *P* is a pawl and *R* a ratchet-wheel, the object of which is to keep the lever *C* in any desired position. *S* is a spring for keeping the furnace door tight against the front, the joint being made with asbestos. Figure 6 shows the air-valve closed, the projections on rod *A* and furnace-door hinge being in contact, and the door *L* down, in position for hauling ashes. Any further movement of the lever opens the furnace door against the tension of the spring *H*, which case is shown in Figure 7.

No data are available for giving an idea of the efficiency of the system, but, judged by the high speed which the Schichau boats have attained, it has proven very satisfactory.

IV.

8-INCH B. L. R. FOR THE U. S. NAVY.

By Lieut. W. H. Driggs, U. S. Navy.

The act of Congress which authorized and appropriated money for, the construction of the Chicago, Boston, and Atlanta, contained a clause stipulating that these ships should be armed with high-power breech-loading rifles. In compliance with this law the Naval Bureau of Ordnance designed and began the construction of three calibres of this class of ordnance, viz, the 5, 6, and 8-inch steel B. L. R. The 5-inch gun is similar in construction to the 6 inch, of which a brief description was given in the last publication of this office.* At the time of writing that description no 8-inch guns had been tried, but during the past year the two guns of this calibre intended for, and now mounted as part of the battery of, the Atlanta have shown gratifying results.

The metal used in the 5 and 6 inch guns was supplied by the Midvale Steel Works, Nicetown, Pa. At the time the contract for the 8-inch guns was awarded, neither this nor any other domestic firm could furnish forgings of sufficient size for so heavy a gun; and the contract had therefore to be given to foreign manufacturers. Since then, however, the Midvale company has so far increased its facilities that it has furnished forgings for an Army gun of this size, and hoops and other small parts for Navy guns fully equal to those of foreign make.

The contracts for the metal for the 8-inch guns for the Chicago, Boston, and Atlanta were given to two English firms, Cammell & Co., and Whitworth & Co. The disadvantage of depending on foreigners for gun steel was augmented by the peculiar business-methods of these firms; for the work furnished by Cammell & Co., under contract, had to be accepted without rigid inspection by our officers whether at the foundry when the ingots were cast, or at the factory when the forgings were completed. Fortunately the pieces from this company were sufficiently near the requirements to be accepted; but had they fallen short, or had flaws developed during the process of machining, the loss would have fallen entirely on the Government. With domestic firms the Government is better protected; for these must permit an inspector to observe the entire process from charging the furnace to finishing the forging, thus furnishing the Department with a complete history of every piece of metal used.

---

*A more complete description may be found in the Proceedings of the United States Naval Institute, Vol. XII, 1886, No. 37.

DESIGN.

The original design and order for the 8-inch guns provided chase hoops out to and including I, see Fig. 1, plate I. After the construction of these guns had been begun, and two of them were nearly completed, it was found that with the new powder (which was then being developed) the chase was somewhat weaker than it should be to endure the strain with a sufficient margin of safety; consequently two additional hoops K, and L, were added to these first two guns, known as Mark I. The guns for the Boston are also known as of the same mark, but have had the hooping carried forward to the muzzle. The addition of the hoops to the Atlanta's guns caused a change of 1.6 inches in the position of the trunnion band. In the case of the guns hooped to the muzzle, the band has been moved slightly forward and the trunnions placed as far forward on the band as possible.

The Chicago's guns will be known as Mark II. They differ from Mark I only in the arrangement of the hoops. The shape of the F hoop, which in I Mark comes down on the tube at its forward end, has been straightened in Mark II, and laps over the rear end of G. The trunnion band has been moved forward, as well as all the hoops in rear of it. The space thus left at the breech end was finished by adding the narrow hoop X.

Since the construction of Marks I and II the Bureau of Ordnance has completed a new design known as Mark III, upon which future guns will be built. The drawing of this mark is shown on Plate II, and differs from the other marks in the following features:

(1) The cylindrical part of the chamber has been increased 2.6 inches in length and decreased 1.0 inch in diameter.

(2) The cone of the chamber has been increased in length 1.0 inch and made uniform up to the compression slope. The cubical contents of the chamber remains the same as in the other marks (3,600 cubic inches), while the cone has a much more gradual slope, thereby greatly decreasing the erosions of the bore. The travel of the projectile, and therefore the capacity of the bore, remains practically the same, viz, 13,544 cubic inches, giving 3.771 expansions.

(3) The length of the hoops has been increased, while their number has been decreased.

(4) The total length of the gun has been increased 6.51 inches, while the exterior diameter of the cylinder has been decreased 1.25 inches.

A general comparison of the two marks is given in the subjoined table:

Mark.	Weight.	Powder charge.	Projectile.	Lengths.					Diameters.			I. V.
				Over all.	Jacket.	Rifling.	Chamber.	Compression slope.	Exterior over chamber.	Interior of chamber.	Tube under jacket.	
	Lbs.	*Lbs.*	*Lbs.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*In.*	*F. s.*
II	28,077	125	250	257.99	99.39	194.16	49.61	1	30.0	10.5	15.8	2,000
III.	25,720	125	250	264.5	100.0	195.795	53.21	1	28.75	9.5	15.0	2,000

MATERIAL.

From the beginning of this new system of gun construction in the United States, the Chief of the Naval Bureau of Ordnance has demanded gun steel of the highest grade, and to the employment of this metal in the fabrication of naval guns (as forming a fundamental part of the question of design) the successful results obtained at Annapolis may be attributed. Without entering upon any discussion of the various grades of hard, medium, or soft steel, it may be said that the peculiar metal selected by the Navy contains all the best qualities of gun steel heightened by tempering and annealing. That is to say, it has great elastic strength, great elongation within the elastic limit, and good ductility.

This statement may be illustrated by a detailed account of the various characteristics of the several parts of the 8-inch B. L. R., No. 1, following. (The specimens tested being 2 inches by ½ inch):

Name of part.	Weight finished.	Elastic limit in pounds.	Elongation after fracture.	Contraction of area after fracture.	Elongation within elastic limit.
	Pounds.	*Per sq. inch.*	*Per cent.*	*Per cent.*	*Per cent.*
Tube	9,528	27,000	25	32	0.10
Jacket	7,665	29,000	20	27	0.10
Hoop A^1	1,938	49,000	27	50	0.15
Hoop A^2	1,795	57,000	24	47	0.20
Hoop A^3	1,765	50,000	23	42	0.20
Hoop B	912	55,000	17	35	0.20
Hoop C	716	57,000	21	46	0.20
Hoop D	622	65,000	18	29	0.20
Hoop E	456	55,000	17	32	0.20
Hoop F	534	41,000	22	38	0.17
Hoop G	523	48,000	28	55	0.15
Hoop H	435	49,000	27	50	0.15
Hoop I	364				
Hoop K	370	54,000	23	55	0.20
Hoop L	319	55,000	25	55	0.20
Trunnion band	1,100	42,000	14	16	0.20
Breech block	314				

These forgings were made by Cammell & Co. Those for No. 3 gun were made by Whitworth & Co., and show much higher qualities.

From this table it is clear that great strength and durability are obtained, while the component parts of the gun can be so arranged as to make each bear its proportion of the strain brought upon it by the discharge.

The subject of steel for high-power guns has been so prominently brought to public attention of late, and so many schemes have been ardently pushed forward, by which the Government was to obtain better guns than those now designed, at much less cost, that a few remarks on this subject may not be out of place in this article.

The opposition to the naval system of gun construction comes mostly from the advocates of steel-cast and cast iron as the proper metal of which to build our modern guns. These, in support of their special methods, cite the old smooth bore Dahlgren and Rodman guns to show the reliable character of those systems; and to prove the unreliable character of the present system, the failures of English guns are offered. In one paper published under the auspices of the Chamber of Commerce of the State of New York, and circulated in pamphlet form, are mentioned several failures of (what are claimed to be) new steel B. L. R. guns, among them being the accident to the 6-inch gun of the H. M. S., Active, and the failure of the gun on board the Collingwood, although neither of these guns was all steel or of new construction. From a late official communication to the English Parliament we learn that since 1875 there have been thirty-one guns reported to have failed in the English services. Nineteen of this number were muzzle-loading guns of old pattern, mostly built of wrought iron; not one was built entirely of steel. Nine others were small Armstrong guns in which wrought iron was used to a greater or less extent. This leaves but three to be accounted for. Of these, one was the 6-inch gun of H. M. S. Active, another the 12-inch of H. M. S. Collingwood, while the third was an old pattern 7-inch Armstrong; all built of wrought iron and steel. So that of the whole number not one was either a steel gun or of late construction; and it may be positively stated that not a single modern high-power steel gun has failed in the English service.

On the other hand, the guns composed wholly or in part of cast-iron, of patterns now in service in the United States, and which are said to be so reliable, have a more damaging record than is generally supposed. In a report made by a joint committee of the Senate in the third session of the Fortieth Congress may be found some very interesting and instructive data on this point. From this report we find that 258 cast-iron guns have failed; as follows:

86 Parrott rifles, from 150 to 30 pounders.
4 Rodman rifles, 12-inch calibre.
2 Rodman rifles, 8-inch calibre.
18 Rodman, 15 and 13-inch S. B.
31 Dahlgren S. B., and rifles of various calibres.
9 miscellaneous guns.

10 burst spontaneously.

98 cracked, fissured, or ruptured before proof.

This is a large number of failures and fails to prove the great reliability of cast iron, or any combination of it with other metals. It is but reasonable that a built-up gun composed of a number of parts should be more reliable than a solid casting, for every part is constantly under inspection until the gun is complete, while with large castings of steel or iron flaws are likely to exist without any indication whatever until they are discovered during proof, or perhaps later in actual service.

The advance in the manufacture of gun steel is largely due to the introduction of the process of tempering in oil and annealing, the advantages of which are clearly shown by Mr. John Coffin, engineer of the Cambria Company, Johnstown, Pa., from whose valuable article in the "Proceedings of the Naval Institute" is taken the following table of tests of soft steel of 60,000 pounds tensile strength:

Untempered.			Tempered.		
Elastic limit in tons per square inch.	Ultimate strength in tons per square inch.	Elongation in inches.	Elastic limit in tons per square inch.	Ultimate strength in tons per square inch.	Elongation in inches.
13	26.8	.737	29.2	45.2	.433
13	27.8	.707	27.8	46	.345
12	27.6	.713	26	39.6	.420
12	28	.633	25.8	41.	.480
13.77	28.11	.596	34.15	49.8	.26
12.18	26.9	.564	34.8	49.4	.202

From these figures we see that the elastic strength has in every case been more than doubled, while the decrease in elongation has not been sufficient seriously to affect the ductility.

This valuable quality of high elastic strength, or the load the metal will stand without being permanently deformed, together with a wide margin between it and the tensile strength, are the main factors to be considered in constructing heavy guns.

Referring to the curve of strength of wall of the 8-inch B. L. R., Plate I, we see that the elastic strength of the metal over the chamber is 22.9 tons per square inch, while the pressure curve for the service loading is but 15.5 tons per square inch, or, in other words, there is an excess of 7.4 tons in which the chamber pressure can be raised before reaching a point that would strain the metal. This high elastic strength has not only given the Navy a safe weapon for firing heavy charges, but has also largely increased the life of the gun, for until the elastic limit is reached there is but little or no deterioration in the power of the metal to resist strain. The life of the new guns will consequently be determined by the erosions in the bore caused by the great velocity of the gases. When these scores become excessive the bore will probably be lined, after which the gun should be as reliable as when new.

Upon this subject a very interesting report was printed in the Mémorial de l'Artillerie de la Marine upon the results of trials made in 1886 to determine the life of the French steel B. L. guns of 65^{mm}, 90^{mm}, 10^{cm}, 14^{cm}, and 16^{cm}, of the model of 1881. The trials were conducted by the Commission de Gâvre, and may therefore be regarded as thoroughly trustworthy. The general deductions from these experiments are as follows:

65^{mm} (2.56 *inches*) *steel B. L. R.*—This gun was fired in all 2,081 times, having been fired 1,182 rounds before the trial for endurance began. During the early trials it was carefully inspected at rounds 33, 462, 907, and 1,182, and up to that time showed no serious erosions, and was otherwise in good condition. During the remaining 899 rounds the gun was charged with 360 grams of powder and a projectile of 2.7 kilograms. Inspections of the gun were made after each 100 rounds, and developed the fact that the erosions increased rapidly for the first four hundred fires, but beyond that the gun deteriorated but slowly, and that at the close of the trial, when the gun had successfully stood 2,081 fires, it was still in serviceable condition, though the erosions were so great that the lands were almost entirely gone. The resistance or strength of the piece was, however, adjudged to be as good as when new.

90^{mm} (3.54 *inches*) *steel B. L. R.*—This piece sustained a fire of 900 rounds, and, in the words of the report, "was then as good as new."

10^{cm} (3.9 *inches*) *steel B. L. R.*—The 10^{cm} gun, after a fire of 1,115 rounds was considered unserviceable from erosions in the bore, but as this was a new calibre, it was thought best to continue the trial, to ascertain, if possible, at what point the piece would fail entirely. For this experiment the charge was graduated so as to give a pressure of 2,700 kilograms per square centimetre (17.2 tons per square inch) for each fire. The firing was continued until 1,295 rounds had been discharged from the gun. At this point the erosions had so increased that the lands just in front of the projectile were entirely gone. At 15^{cm} (5.9 inches) from the commencement of the rifling the erosions reached a depth of 3^{mm} and decreased gradually thence to a distance of 40^{cm} from the seat of the projectile where they disappeared. At the 1,295th fire the breech-block stuck so that it was with great difficulty removed. As a result of this trial the life of this piece has been set at 1,000 rounds.

14^{cm} (5.5 *inches*) *steel B. L. R.*—The 14^{cm} gun with a charge of 13.7 kilograms imparts a velocity of 590 metres (1,935 f. s.) to a projectile of 30 kilograms. This loading gives a pressure in the chamber of 2,400 kilograms per square centimetre (15.2 tons per square inch). It was found that serious erosions were caused after a fire of 424 rounds, 91 of which were with reduced charges. Pending further trial the life of the piece has been set at 400 full charges.

With the 14^{cm} Model of 1870, which fires a projectile of 28 kilograms, with a muzzle velocity of 406 metres (1,332 f. s.), 3,500 rounds are allowed before condemning the gun.

16^{cm} (6.3 *inches*) *steel B. L. R.*—This piece was fired 595 rounds; 539 being with service and 56 with reduced or exercis charges. The heavy charge (projectile 45 kilograms, powder 21.6 kilograms) gives a velocity of 600 metres (1,968 f. s.). During this firing the breech mechanism worked admirably throughout. It was not until after 338 rounds had been fired that any change could be observed in the bore. After 445 rounds the erosions had increased sufficiently to decrease the muzzle velocity 10.9 metres, but did not become serious until about the 489th fire. After the 589th fire they had increased to a depth of 6^{mm}.

Guns of this character can only be regarded as unfit for service in war after they have lost their accuracy or when so much weakened that a rupture of the piece may occur. This piece did not begin to lose its accuracy until between the 457th and 545th round (or, not counting the exercising charges, between the 401st and 489th fire), while its power to resist rupture was never questioned. In view of these facts, the life of the gun has been provisionally set at 400 full charges.

From the foregoing it is evident that the life of each calibre was determined solely by the erosions in the bore; that the power to resist rupture was never impaired beyond a point of safety; and that relining the bore would have made the guns almost equal to new ones.

CONSTRUCTION.

Up to the present time eight 8-inch B. L. R. guns have been built for the naval service Of this number four were assembled at the Washington yard, two at the South Boston Iron Works, and two at the West Point Foundry. Three were constructed of forgings from Cammell & Co. and five of forgings from Whitworth & Co. All the trunnion bands, breech blocks, and the additional hoops which were not in the original design were furnished by the Midvale Steel Company. Owing to great expense of forging, the trunnion bands were cast of steel but not forged. The construction of the first 8-inch gun was begun in September, 1883, and completed in March, 1886, thus being twenty-nine months in process of manufacture. Later guns were finished in less time, but it is not probable that, with every facility to be placed in the new Washington factory, it will be possible to make an 8-inch gun in less than six or seven months.

The main features of construction are the same for all calibres of the new guns, except that for the smaller ones the forgings other than hoops supplied by the Midvale Company, were delivered rough-forged and were bored and turned at the Washington yard, when, if no imperfections were discovered, they were returned to Midvale for tempering and annealing. All hoops bought of the Midvale company were delivered at Washington rough-turned and bored, oil-tempered, and annealed, having been provisionally accepted on the tests of specimens sent by the Naval Inspector at the works.

These test pieces are cylinders 2 inches long by ½ inch in diameter, finished at each end (beyond the length of 2 inches) by a heavy screw for holding the specimen in the testing machine. These test pieces are cut in a transverse direction perpendicular to the axis of the hoop and at right angles to each other, and are intended only for testing the transverse strength. Only two are taken, both of them from the end that was down when the casting was made.

The tests for tubes and jackets are derived from eight specimens of each piece, four from each end, two of these being tranverse and two longitudinal.

The forging is not finally accepted until the gun is finished, so that should any flaw be discovered during the machining the loss falls entirely upon the founder or contractor.

The turning of the various parts is conducted with the greatest care and accuracy. For measuring interior diameters light steel bars having hemispherical ends are fitted by the use of a micrometer scale to the exact interior diameter of the piece.

For measuring exterior diameters fixed calipers are used, which are adjusted by the use of the small steel bars and a micrometer scale to the exact exterior diameters required.

The interior of the jacket being finished as accurately as possible, it is then measured by star gauge at intervals of 1 inch to ½ inch for its entire length. To each of these diameters (which are exact to 0″.001 of an inch) is added the amount of shrinkage for the jacket and each inch of the length of tube under the jacket turned to fit exactly the corresponding increased interior diameters. The amount of shrinkage is determined by the qualities and diameters of the two pieces which come in contact, and may differ considerably in different guns, or in the different parts of the same gun. Thus the amounts allowed for the first 8-inch B. L. R. were as follows:

	Inch.
Jacket	Add 0.011
A hoops	Add 0.031
B hoops	Add 0.031
C hoops	Add 0.031
D hoops	Add 0.027
E hoops	Add 0.023
F hoops	Add 0.024
G hoops	Add 0.022
H hoops	Add 0.021
I hoops	Add 0.020

These amounts are derived from calculations and are based upon the comparative qualities of superposing pieces, and are intended to be so arranged as to cause each to arrive at its elastic limit at the same time.

For this reason the further a piece is removed from the pressure of the gases the greater the tension of shrinkage. For instance, an inspection of the above table shows that while the tension of the jacket is that derived from a compression of 0.011 of an inch, that of the hoops is from a compression of 0.031 of an inch.

The tube and jacket being ready to be put together, the former is placed in the shrinking-pit, muzzle down, on heavy blocks. From these blocks extends a stout iron bar up through the bore and some distance beyond the breech. The tube stands in such a position that the forward end of the jacket, when in place, will come a little above the floor of the foundry. At the level of the floor is built a water-tight dam surrounding the tube, and about 2 feet deep. The tube being thus prepared, the jacket is expanded by heating it in a sheet-iron cylinder with a light-wood fire, heaping on the wood until the embers cover the entire jacket. At intervals these are brushed aside and the jacket calipered. When it has expanded sufficiently to allow of its passing easily over the tube, a sling band is put on with set-screws, the crane hooked on, and the jacket swung over and lowered to its place on the tube. When nearly in its seat the chain of the crane is let go and the jacket falls about 5 or 6 inches, thus setting it up hard on the shoulders. In this position a cross-bar is placed over the breech, and by means of it and the bar through the bore (the end of which has a nut and screw) the jacket is held firmly in place, while at the same time water is put in the dam around its forward end, ice being added to keep the temperature down. In this way the jacket is made to nip at its forward part, so that all further contraction is towards this point. The hoops are shrunk on with the gun horizontal (working from the trunnions each way) until only the trunnion band remains. This piece is screwed on cold. The narrow band around the cylinder of the gun to which the elevating gear is attached is of wrought iron, and is shrunk on after the gun is otherwise complete.

The method observed at the South Boston Iron Works for expanding and shrinking on is an improvement on that just described. At this factory the gun rests horizontally on a frame. The piece to be shrunk on is placed on a car at such a height that the centre of the hoop corresponds with the centre of the bore. While in this position it is expanded by the heat from exterior and interior circles of gas jets. When it has opened the necessary amount to slide easily in place, the car carrying the hoop is run under the gun to its proper position, a hydraulic press holds it firmly in place while streams of water from circular pipes cool it at the end at which it should first nip.

This method has many advantages, for by it the hoop can at any time be calipered, and overheating is thus avoided. Also, the heat is much more uniform, the hydraulic press holds the piece more securely in position than the iron rod used at the Washington yard, and the means of cooling is fully equal to the other. Undoubtedly the naval ordnance factory now being established will have the most approved means of shrinking on.

The gun being assembled, it is returned to the lathe and its exterior finished down to the required diameters. The bore is then smooth-bored to the diameter of the lands, and the chamber reamed out and coned. This latter work is done by a special cutter, the exact shape of the cone and slopes, and which is supported in the cylinder of the chamber and bore.

The gun is now ready for rifling. It is placed on a planing-machine and rests in collars, so that it can be given a motion of rotation as each cut is made. The rifling bar is set in a horizontal position in the prolongation of the axis of the bore, and so secured that it has no motion of translation. The curve of rifling is cut on the bar in the shape of a slot. Just in front of the muzzle of the gun the bar passes through a support, resting on the planer-bed, in which there is a stud that enters the slot of the bar. As the gun moves forward and backward with the bed of the planer, the rifling bar is made to revolve (by means of the stud in the muzzle support and the slot in the bar), so that the cutter in its head reproduces the curve of rifling in the bore of the gun. As each cut is finished the gun is turned in its supports.

The rifling adopted for the 8-inch guns is of the polygroove system and increasing twist. There are thirty-two lands and thirty-two grooves. Beginning at the junction of the bore with the powder chamber the twist is one turn in 180 calibres, increasing on the curve of a semi-cubical parabola to one turn in 30 calibres, which is reached at 13.16 inches from the muzzle. For the remaining distance the twist is uniform.

The depth of the grooves is .05 of an inch. The width of the lands at the seat of the projectile .30 of an inch on top and .31 of an inch at the bottom. These widths increase towards the muzzle, where they are .35 and .36. This peculiar shape keeps the band of the projectile pressed into the grooves and prevents the escape of gas.

This gun, like the 5 and 6-inch guns, is fitted with the De Bange obturator, slightly modified and improved. The means of working the breech block is also more elaborate. To readily and quickly move so heavy a block as 314 pounds, some mechanical means had to be employed. For this reason a crank has been fitted to the arm of the plug. On the spindle of the crank is a pinion working into a ratchet on the exterior of the jacket. (See Plate II.)

Fig. 1 represents the rear, and Fig. 2 the side view, of the breech mechanism, the lower part of the tray *m* being shown in Fig. 2 in section, to more clearly illustrate the working of the retracting screw. The plug is here shown in position for withdrawing or closing. To close the breech, the catch *g* is drawn out, releasing the crank from the arm of the plug, when by revolving the crank from left to right the arm of the plug is turned to the right by means of the pinion B and ratchet C. When one revolution of the crank has been made, the catch *g* is again in position to hold it over the arm of the plug, but is prevented from doing so by the pin *f* in the arm traveling upon the projection *o* (Fig. 1), which presses it out until its end is flush with the outer surface of the plug arm, so that the catch *g* passes freely over it. The second revolution of the crank brings the arm of the plug against the stop *y*, and at the same time the catch *g* on the crank is forced into a recess in the arm by means of a spring (not shown) in the handle, and thus, the crank being held firmly in position, the plug is securely locked. As the arm of the plug travels from left to right the safety tongue P is drawn up by means of the lug *h* moving in the slot *i*. Until near the end of its travel the tongue P is down and in front of the firing attachment, and does not rise sufficiently to clear it until the plug is in place for firing.

To withdraw the plug for loading, from the position shown in the plate, the crank D (Fig. 2) is revolved from left to right, which in turn revolves the screw E, on which is a carrier or block, S, into which the lower part of the plug fits when the handle is vertical, as in the plate. It will be noticed that the pitch of the screw increases from the gun towards the crank handle, so that the plug is started slowly but forcibly. When the plug has arrived at the end of the tray the latch *k* is raised, when the tray, nearing the plug, is swung around on the hinge T by hand, using the handles on the plug for this purpose.

In regard to the strength of the 8 inch B. L. R., mark II, an inspection of Plate I will show the main features, also the strength of walls and pressure curve for the service charges. It will be seen that the weakest point of transverse strength is just forward of hoop G, where it is 4.5 tons per square inch in excess of the pressure in the bore. So that there is a margin of 4.5 tons per square inch before reaching a point that would even strain the gun, while the limit of safety would be far in excess of this amount.

Longitudinally the gun will stand (inside the elastic limit) a pressure of 38.4 tons per square inch. Twice during proof firing shell have been prematurely exploded in guns of similar type, but, beyond some slight scratches from the rough edges of the broken pieces, the guns suffered no injuries. The strains to which guns are subjected, transverse and longitudinal, are so distributed that an undue amount shall not fall on any one part. For this reason the tube is relieved as much as possible from longitudinal strain by placing the screw-plug in the jacket.

Longitudinal strain sustained by the breech-plug is transferred by the threads of the screw to the jacket, which is partly held by the grip of shrinkage and partly by the shoulder on its front end taking against the hoop B, which in turn transfers it to the trunnions through the screw-threads on the trunnion band. The tube is made to resist forward motion by the shoulder in rear of hoop E, which has a shoulder that rests on D, D one that rests on C, and C a shoulder that rests on the shoulder of the trunnion band, so that by screwing up on the trunnion band the hoop C is drawn close up against B, thus locking the two systems of hoops and preventing any longitudinal motion of the tube between the breech and the hoop E. The A and chase hoops add only transverse strength.

SIGHTS.

Thus far the sights for the 8-inch guns have been designed and graduated from calculations only, as the proving ground offers no facilities for verifying the work or marking the sight-bar from actual trials.

Two lines of sight have been provided, one on the left side for long ranges and one over the central line for close quarters. The side sights consist of a finger point on the left side of the trunnion band and a bar working in a box on the rear face of the last hoop. This bar is raised and lowered by means of a worm, so that it requires no clamp-screw, and remains at the height given it. To compensate for the drift due to rifling the screw-bar is set at a permanent angle of 0°45′ to the left of the vertical, and besides this incline it is set bodily to the left 0.17 of an inch. This arrangement gives a very accurate line of sight. The head of the bar is provided with an open-sight notch, so that the target may be seen above and below the line of sight. There is also a sliding leaf, which is graduated in degrees of horizontal angle, simply for convenience, as it has no reference to the adjustment of drift or any other permanent inaccuracies of sighting, but is simply for making corrections for the wind, speed of ship, or speed of the enemy, and is to be set experimentally.

The central line of sights being intended for close quarters, is only available up to 4,000 yards. The rear sight of this line has two short bars, one marked up to 2,000 yards and the other from 2,000 to 4,000 yards. There is but one sighting head, which is shipped on the bar in use. The sliding leaf of the rear side sight is omitted from the rear central sight.

PROJECTILES.

At present the only projectiles furnished for the 8-inch guns are cast-iron, common shell, with the ordinary Schenkle fuze, or rifle-time fuze with igniter, in the point. Armor-piercing shell, of steel, have been designed, but the attempts to manufacture them with such characteristics as would pass the Bureau's tests, have thus far been unsuccessful. New fuzes, combining both time and percussion methods, and steel shell, are being experimented with, and, when perfected, will be furnished to the service.

Like the shell for smaller calibres, the 8-inch obtains its rotary motion from a soft copper band, 1.35 wide, which is forced into an undercut score about 2 inches from the base of the shell. The bottom of the score is corrugated to prevent the copper from turning. This band projects .07 of an inch beyond the sides of the shell and is forced into the grooves by the compression slope, thus cutting off any escape of gas.

POWDER.

The powder for the guns mounted on board the Atlanta was furnished by the Westphalia Powder Company, of Germany, and is known as the Brown Prismatic. The size and shape of grain is the same as that furnished for the 6-inch guns, but the ingredients are so proportioned as to give a slower rate of burning. Trials lately made with samples of powder from the Dupont Company show that they can manufacture powder equally as good as that bought abroad, so that the other ships will be supplied with this domestic brand. The service charge of this powder gives a 250-pound projectile a muzzle velocity of 2,000 f. s., while the chamber pressure does not exceed 15 tons per square inch.

With the usual loading (250-pound projectile and 125 pounds of powder) the calculated penetrations in wrought iron are as follows:

Muzzle, 17.1 inches.

1,000 yards, 15.1 inches.

2,000 yards, 13.6 inches.

The calculated range for this loading, with the extreme elevation which the carriage permits (20°), is about 8½ statute miles.

One hundred and twenty-two pounds Westphalian powder was selected as the proper charge for the Atlanta's 8-inch guns.

TRIAL OF THE 8-INCH B. L. R.

The trial of the first 8-inch gun was commenced at Annapolis, July 31, 1886.

As is the custom in these trials, the early firing was mainly conducted with a view of obtaining suitable powder. The results of the first twelve rounds are given in the table below:

Date.	Numb'r of rounds.	Weight of projectile.	Weight of powder charge.	Best result.	
				Velocity at muzzle.	Pressure per square inch.
		Pounds.	*Pounds.*	*F. S.*	*Tons.*
July 31, 1886	3	250	110	1,996	15.9
August 24, 1886	3	250	120	1,990	14.4
September 22, 1886	6	250	123	2,013	15.5

The act of Congress of 1886 required a special test for the B. L. R. guns, as follows:

> One or more rifled cannon of each type constructed at the cost of the United States for the Navy shall be publicly subjected to the proper test for endurance, including such rapid firing as a like gun would be subjected to in battle. This test shall be under the direction and to the satisfaction of the Secretary of the Navy, and if such guns do not prove satisfactory, the type they represent shall not be put in use in the naval service.

In compliance with this law it was decided to subject one of each calibre of the new guns to a fire of ten rounds discharged as rapidly as possible, performing all the duties of the piece as would be done on shipboard and in battle.

This trial, known as the "statutory test", took place at Annapolis, November 4, 1886.

A crew was selected from among the laborers about the proving ground, and to acquaint them in some measure with the manner of handling the gun a few preliminary drills were given them.

A shelter distant from the gun 45 feet was provided for the crew.

The projectiles were placed near the gun, while the powder charges were in a magazine 180 feet away, which distance the powder-men had to travel at each round. The gun was mounted on its service carriage. It was decided by the Board conducting the trial that the ten rounds must be fired as rapidly as possible, with no delay to wait for the dissipation of smoke, or for any pointing except such as could be done while the loading and sponging was going on. The Board took the ground that this represented the extreme circumstances of an action at close quarters, and that if time were allowed for pointing, the number of rounds should be greater than ten. From the start the firing was hurried; time, however, was taken to thoroughly sponge after each round. For this a wet sheep-skin sponge was passed eight times the entire length of the bore after each fire, while the mushroom was wiped off also at each fire with a wet marine sponge.

The crew were stationed as follows:

Attend breech-block mushroom, &c	2
Sponging	3
Loading tray and loading	3
Training	2
Powder-men	4
Total	14

The gun was loaded with 121 pounds of Westphalia 8-inch powder, and a 250-pound shell. The time occupied in firing each round was as follows:

	Time taken from first fire.
Round 1.	
Round 2	1^{m}22^{s}
Round 3	1 22
Round 4	1 28
Round 5	2 27
Round 6	1 13
Round 7	1 42
Round 8	2 01
Round 9	1 51
Round 10	1 42
Total	15 08

The total number of ten rounds was fired with an untrained crew in 15^{m} 08^{s}. When it is considered that before each fire the entire crew were obliged to cover themselves behind the shelter, the time is remarkable.

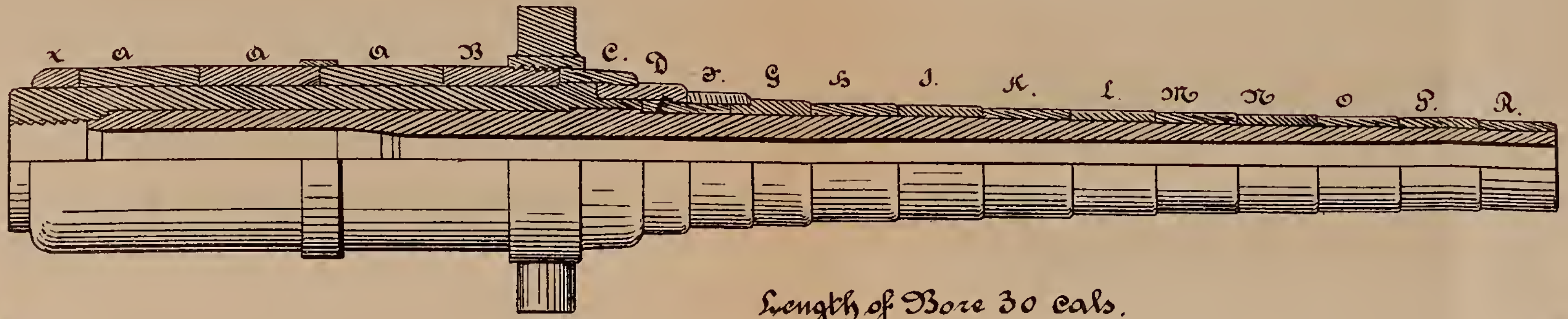
The muzzle velocity obtained on this trial was 1,991 foot seconds, with the moderate pressure of 14.6 tons. After the conclusion of the trial the gun was carefully star-gauged, and showed no signs whatever of any change in shape except a slight decrease of .001 of an inch in the chamber, which was supposed to be due to that part not having a perfectly clean surface.

The muzzle heated to a degree sufficient to evaporate the water from the sponge; the exterior of the breech was less heated, and the chamber was scarcely warm. The mushroom and its fittings heated considerably, so that some slight binding of the parts was caused. This will be remedied in the later guns by allowing a little more room for the parts to expand. As it was, the trial was eminently successful. The mounting worked perfectly, the recoil being checked in the short distance of 2 feet; while the return of the gun to the firing position was prompt and easy. The elevating gear also worked admirably. The heavy downward thrust of the breech was taken up by the coned friction-wheel so that the change in elevation was only about 1° and the carriage relieved of any undue strain.

Up to the present time this gun has fired twenty-six rounds and is in perfect condition.

Plate I.

8 inch B.L.R. Mark II.



Length of Bore 30 cals.

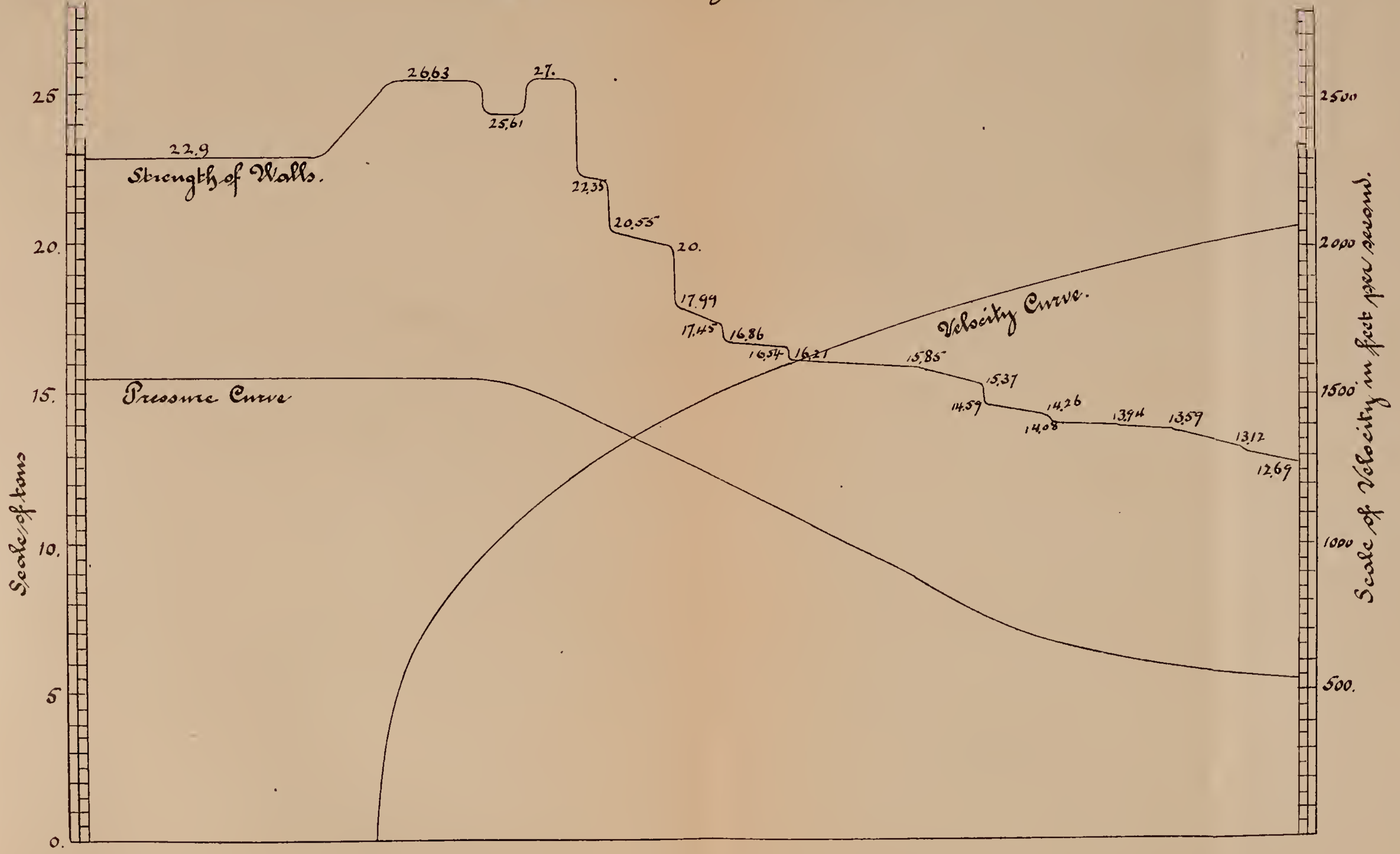
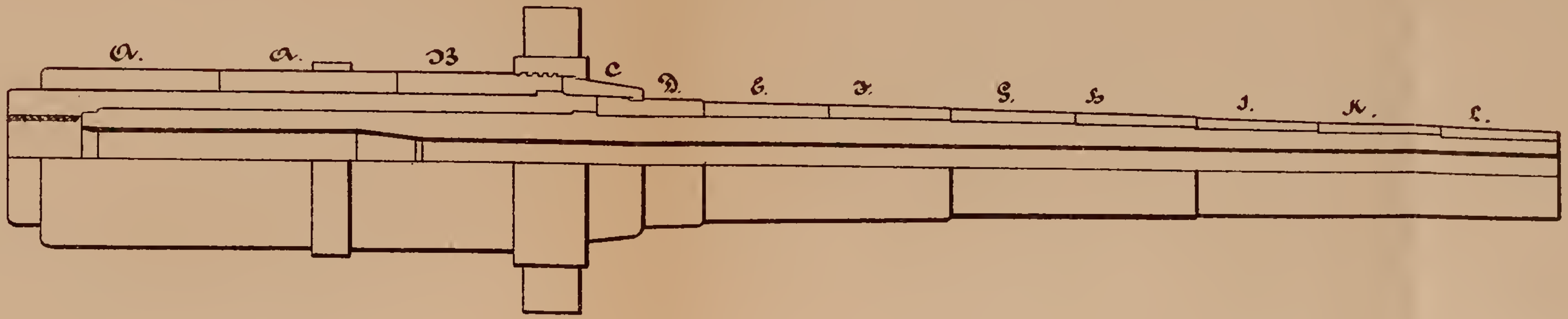


Plate II.

Naval 8 inch B. L. R. Mark III.



Breech Mechanism.

Fig. 1.

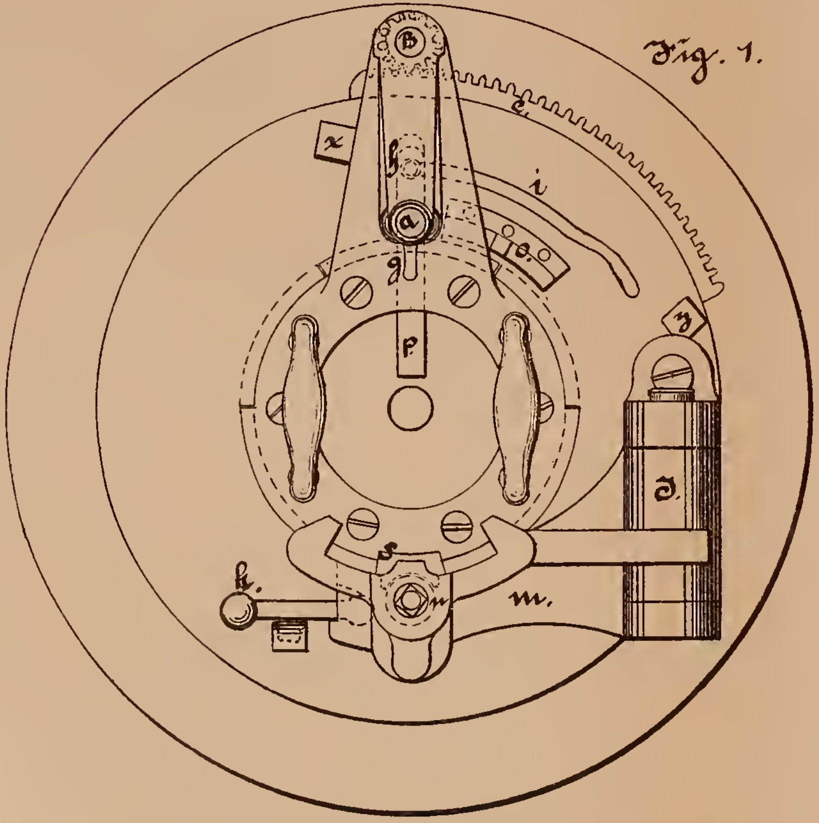
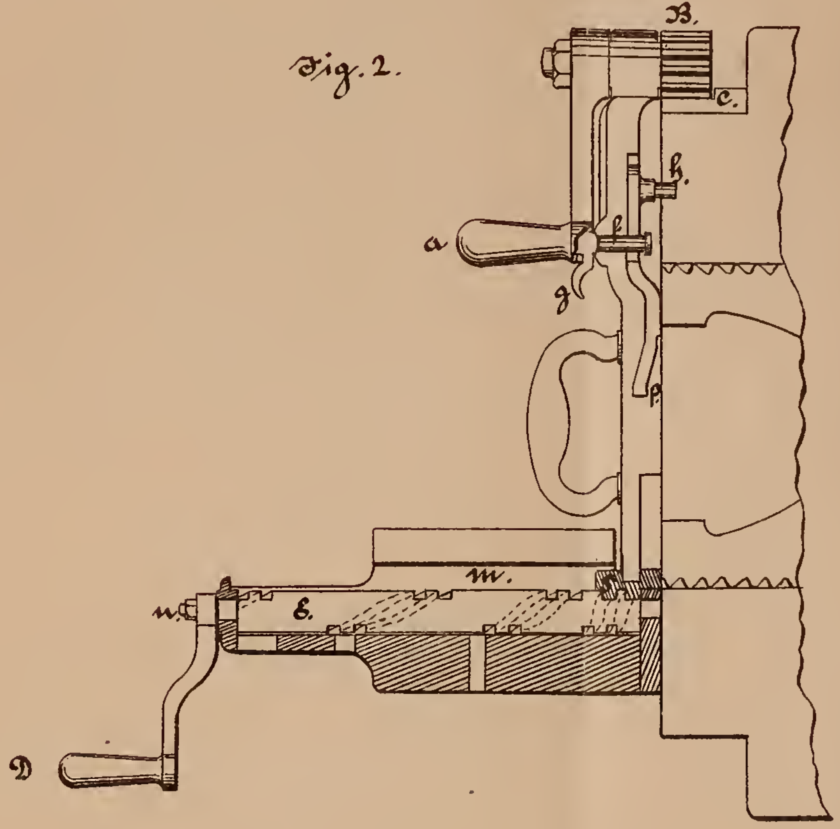


Fig. 2.



V.

NOTES ON THE POWER AND DISPOSITION OF GUNS.

By Lieut. W. I. Chambers, U. S. N.

In most of the recent absorbing controversies respecting the value of torpedoes and torpedo-boats the gun has been somewhat neglected, and in predicting the effect of the practical advent of torpedoes upon future constructions the topedo alarmists seem to have considered the gun mainly from its value as an armor-piercing machine.

The real value of the gun, however, rests mainly upon its adaptability to various uses, and no study of the transformations in naval architecture which may result from the development of the torpedo can be perfect without a due consideration of the new duties which would thus be imposed upon the gun.

The gun has always responded nobly to the demands for increased destructive power in hurling both shells and armor-piercing bolts, and if, to accommodate the demands of the torpedo, a total abandonment of side armor, even at the water-line, is seriously contemplated, it should be done only after due attention to the possible transformations which may be wrought in the older and more adaptable weapon.

Lieut. Em. Weyl is one of those French officers who do not agree with the torpedoists concerning the doom of armored ships, and in his thoughtful treatise (*Questions Maritimes*) published in 1885, he says:

> The gun still remains an important weapon of attack. If the use of the torpedo results in our building unarmored vessels, the gun no longer need be an armor-piercing machine, and it may revert to the simpler state of a machine for throwing a great mass of shells in a small space of time. It may become a rapid-firing gun of large calibre, throwing shells containing large quantities of explosive material. If so, the constructor will again be required to protect certain parts, again the armor-piercing properties of the gun will be developed, and again the race between guns and armor will begin.

The "curve of progress" has undoubtedly been pointing toward the curved deck, or internal armor and coffer-dams, for water-line protection for several years, but before abandoning the vertical belt a few judicious experiments with "torpedo-shells," which are yet in the infancy of development, would seem to be advisable. The holes made in a cofferdam side by numerous small projectiles, or by larger armor-piercing projectiles, would possibly not imperil the stability of a ship, but the result of a gap made in unarmored sides near the water-line by high-explosive shells would at least be very serious.

Krupp has been experimenting with "torpedo-shells," and we have it on the authority of Herr Max von Foster, superintendent of the gun-cotton factory of Wolff & Co., Walsrode, Germany,* that, after a series of tentative experiments, he has demonstrated that ordinary shell may be converted into gun-cotton shell very readily and fired at great range from ordinary cannon, mortars, and other ordnance by means of ordinary powder. He expresses the opinion that for throwing projectiles from guns there should never be used anything but the compactest and cheapest power-developing agent, such as gunpowder. He says:

> We are convinced that gun-cotton shell will perform much important service, even if they do not work wonders. The effect of high explosives is overrated; for example, upon a small area of armor no high explosive will produce nearly so much effect as will be produced by a steel shell from a 30 or 40 centimetre cannon. We believe that shell charged with high explosives are to play a great part in the future, even though they do not accomplish as much as is reasonably expected from them. For the very reason that they will not work wonders, it is our further opinion that the high explosives must be so adapted to them that they may be employed in ordnance as it exists.

Commander A. S. Barker, U. S. Navy, also in the same volume, page 561, after describing his significant experiments in firing dynamite from guns, says:

> My prediction in regard to the use of these shell is already being fulfilled. I am glad that our own Government is taking a deep interest in the subject. Congress has appropriated $350,000 for the construction of a pneumatic dynamite-gun vessel which shall carry guns guaranteed to throw projectiles containing 100 pounds of dynamite, *or other high explosive*, a distance of at least 1 mile. Dare any one assert positively that our 15-inch guns cannot do even better than that?

The effect of a highly explosive shell fired from a heavy gun may well be compared to a blow from a ram, and if, as is probable, the gun continues to be the prime weapon in naval contests, the disposition of guns will remain an important feature in naval design.

The method described in General Information Series, No. V. p. 96, of graphically expressing the gun or battery powers of different ships, though hastily devised, seems still to afford a fair and instructive means of comparison. It is generally conceded that the gun power of a ship in a given direction is fairly represented by the total energy at 1,000 yards of one round from all the guns in the ship that can be brought to bear in that direction. In these diagrams the complete circle is divided into sectors of 30° each, and the area of each sector represents comparatively the sum of the energies of one round from all the guns (except those of the secondary battery) which can be brought to bear in that sector, without changing the ship's course more than 5°.

---

* See Proceedings of U. S. Naval Institute, vol. xii, No. 4, pp. 601, 602; translation by Lieut. Karl Rohrer, U. S. N.

There being twelve sectors in each diagram, the *total* area represents the gun power of a ship in twelve rounds, one round being fired in each sector.

It should be distinctly understood, however, that these areas represent energies and therefore comparative armor-piercing powers at 1,000 yards, and not the bursting effect of the shell used. If side armor should come to be abandoned, diagrams representing the bursting effect of one round of shell would probably prove instructive.

The energies used in the calculations for areas are given in the following table:

Calibre and class of gun.	Energy at 1,000 yards.
English and United States.	*Foot-tons.*
16.25-inch (110-ton) B. L. R	45,000
13.5-inch (68-ton) B. L. R	31,300
12-inch (48-ton) B. L. R	22,500
10-inch (26-ton) B. L. R	13,000
9.2-inch (22-ton) B. L. R	9,000
8-inch (13-ton) B. L. R	5,300
7-inch (9-ton) B. L. R	3,700
6-inch (4-ton) B. L. R	2,600
5-inch (2-ton) B. L. R	900
16-inch (80-ton) M. L. R	26,600
12-5-inch (38-ton) M. L. R	11,000
12-inch (35-ton) M. L. R	8,000
11-inch (25-ton) M. L. R	5,500
10-inch (18-ton) M. L. R	4,300
9-inch (12-ton) M. L. R	2,700
8-inch (9-ton) M. L. R	1,800
7-inch (7-ton) M. L. R	1,300
64-pounder M. L. R	522
Blakely 100-pounder M. L. R	658
30-pounder M. L. R	208
XI-inch S. B	650
VIII-inch S. B	302
32-pounder S. B	142
French.	
42 cm. (16.5 inches), model 1875	31,600
37 cm. (14.6 inches), model 1875	26,800
34 cm. (13.4 inches), model 1875	21,000
27 cm. (10.6 inches), model 1875	10,300
32 cm. (12.6 inches), model 1870	10,800
27 cm. (10.8 inches), model 1870	6,900
24 cm. (9.45 inches), model 1870	4,500
19 cm. (7.6 inches), model 1870	2,500
16 cm. (6.3 inches), model 1870	1,500
Krupp.	
30.5 cm. (12 inches) 48 ton	21,200
26 cm. (10.2 inches) 22 ton	10,000
24 cm. (9.45 inches) 20 ton	9,000
17 cm. (6.7 inches) 7 ton	3,000

A comparison of the diagrams for the older ships, such as the Invincible, Teméraire, Alexandra, and Superb, with those for the later ships gives a fair idea of the advantage in power that modern high-power breech-loading ordnance has over the older muzzle-loading guns. A comparison between the diagrams for the Alabama and Kearsarge and that for the Archer (Plate III) gives a fair idea of the modern improvements in battery power.

This method of comparison especially emphasizes the disadvantage of comparatively small arcs of train. The diagrams of the Shah, Huascar, and Almirante Cochrane (Plate III) are of interest in connection with the contests between those ships, and would seem to indicate that the guns of the Huascar are better disposed, weight for weight, than those of the other two ships, and that the advantage is gained by the larger arcs of train of the Huascar's guns. It also shows either that the Shah's armor-piercing guns were badly disposed for the tactics she was obliged to adopt, or that her battery was composed of too many light guns to combat an armored antagonist.

The diagram for the Italia (Plate I) differs from that given in last year's publication, because it has been ascertained that one pair of her heavy guns has a dead angle of 20° ahead and the other pair a similar angle of 20° astern (owing to the position of fixed ventilators), and that she carries fewer 6-inch guns than was originally intended, the number having been reduced from sixteen to eight.

The diagram for the Renown (name changed to Victoria) (Plate I) differs slightly from that previously published, because her stern pivot-gun is a 10-inch B. L. R., in stead of a 9.2-inch B. L. R. as was originally intended.

The diagram for the Nile (Plate I) also differs from the one previously published. This vessel is designed to mount two 68-ton B. L. R. in each turret instead of one, thus giving her a fine display of battery power.

These ships, the Nile and Trafalgar, should grow in popularity, since they combine the elements of offense and defense in such a satisfactory degree.

The diagram for the new Spanish cruiser building by J. & G. Thompson & Co., Clydebank, the details of which were not fully known when the last diagrams were published, is now correctly given for the Reina Regente (Plate III).

The primary battery of this vessel consists of four 24^{cm} (21 ton) B. L. R. and six 12^{cm} B. L. R., mounted separately at the sides. Her battery power could be greatly augmented by having the 24^{cm} guns mounted in pairs on the middle line, thus allowing four of the 24^{cm} guns to fire abeam instead of two as now arranged.

The advantages of mounting guns in pairs on the middle line will be apparent from a comparison of the diagram for the Archer with that for a fictitious vessel named the Improved Archer (Plate III). The latter mounts but four 6-inch guns in pairs on the middle line, while the Archer mounts six 6-inch guns on side sponsons. The Improved Archer thus fires as many 6-inch guns ahead as the Archer, and four 6-inch guns abeam to the Archer's three.

The advantages of such a disposition are not only improved battery-power, but a reduction of about 28 tons in weight of guns and ammunition, and an avoidance of the use of sponsons projecting from the ship's sides. Sponsons are objectionable, (1) because the gun-platforms are subject to damage by a rub from a hostile ship (such as was experienced when the French Bouvet tried to ram the German Meteor, off Havana, during the Franco-Prussian war), and (2) because they necessarily weaken the sides through which they cut.

It may be objected that the ship's rig and the disposition of boats might interfere with the proposed change, but sufficient attention has been given the design to know that this change may be made without reducing the power and efficiency of either sails or boats.

The diagram of the Catherine II is apparently perfect, but when it is considered that it requires six of her heavy guns, mounted in pairs at the apexes of her triangular casemate, to obtain this diagram, and that nearly the same power could be obtained from four guns of the same calibre, the policy of such a disposition of weight may well be questioned. By suitably mounting two pairs of her heavy guns on the middle line, the diagram would be the same, with the exception of the two end sectors, in which the power represented would be that of two 12-inch and four 6-inch B. L. R., instead of four 12-inch and four 6-inch B. L. R.

The diagrams of those ships having the turrets mounted *en echelon* do not compare favorably with those of ships having the turrets mounted on the middle line. The prime object of the *echelon* arrangement is, of course, to obtain powerful end fire; but even in the ships in which this is said to have been accomplished much has been sacrificed in weight and simplicity. Five feet is the least distance determined upon by the French to place the sides of the superstructure of the Hoche from the blast of her 27-centimetre guns, firing in line with the keel; and it is doubtful if many ships designed with turrets *en echelon* could obtain end fire from more than two heavy guns at once without injury to the superstructures and other fittings on the upper deck. There are several disadvantages pertaining to this arrangement, aside from the obstructed or broken arcs of fire of its heavy guns. The unsymmetrical distribution of heavy weights which it entails must produce unusual torsional strains on the hull and divide the ship internally in a complex manner. A complete ship, like any of the numerous inventions contained within her, is best understood, and most efficiently handled when her working parts and details are reduced to the simplest bearings consistent with the completeness and finish of the design.

In the older sea-going turret ships, such as the Preussen, Monarch, and Huascar, the end-fire was comparatively weak, owing to the high ends which were considered necessary, and this doubtless led to the *echelon* arrangement of turrets, after several attempts to attain satisfactory end-fire from the central casemate batteries; but now that barbettes, and even turrets, are mounted high above water, and clear unobstructed arcs of fire can be had from one side to the other, the simpler method of mounting the guns on the middle line, and at the sides, is being adopted in most of the new constructions.

The economy of mounting the heavy guns in pairs arises not only from the increased power thus obtained from a given weight of guns, but from the fact that it requires but little more armor to protect two guns than to protect one. It also requires more machinery to work two guns separately than in pairs, and the magazine and ammunition supply arrangements of guns mounted separately are necessarily more complicated, and require more men to operate them than those mounted in pairs.

The French idea in mounting their heavy guns singly in three or four armored barbettes is evidently to so distribute the gun power as to leave a reserve of heavy guns in event of damage to one or more. But the demands for economy in weight are so great that two armored structures widely separated would seem to furnish as satisfactory a scattering of the heavy gun power as is justifiable.

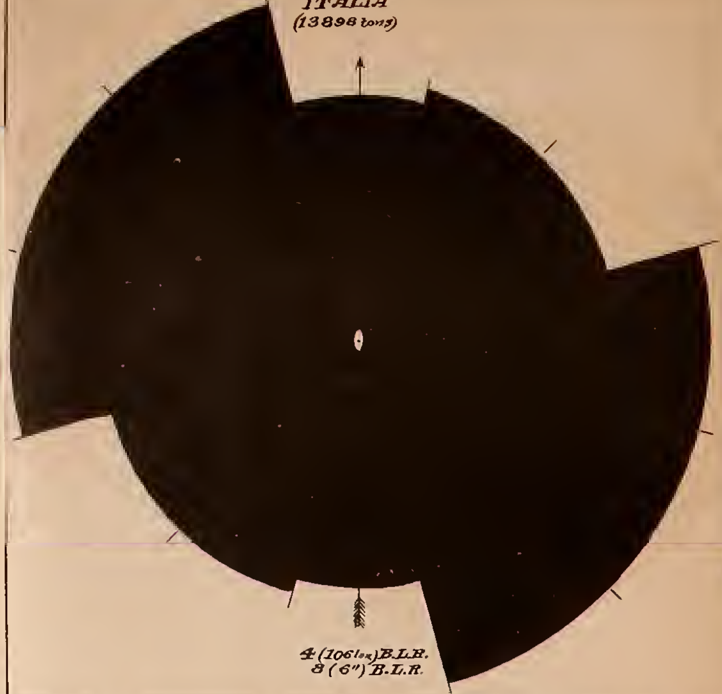
Guns mounted on the middle line suffer less disturbance in rolling than those mounted either in the waist or *en echelon*, and their fire should be correspondingly more accurate.

A comparison of the diagrams for the sister ships Hoche and Magenta doubtless indicates the sacrifice made in battery power to protect the heavy guns of the Hoche by heavy armor. Had her guns been mounted *en barbette*, as in the Magenta, her waist guns probably would also have been of 34 centimetres calibre instead of 27 centimetres.

The late Commodore Parker once said that his war experience taught him to believe in mixed batteries of large and small guns, and the diagrams seem to agree with this conclusion. If the principle thus enunciated were applied to a vessel of the Newark type, for example, and the weight of guns and ammunition distributed among four 8-inch B. L. R., mounted in pairs on the middle line, and six 5-inch B. L. R. (or six 30 pounder rapid-firing guns) mounted in broadside, she would have a "battery-power" ahead and astern of 10,600 foot-tons, and abeam of 21,200 foot-tons, from the 8-inch guns alone, in contrast with 10,400 foot-tons at the ends and 15,600 foot-tons abeam obtained from a battery of twelve 6-inch guns.

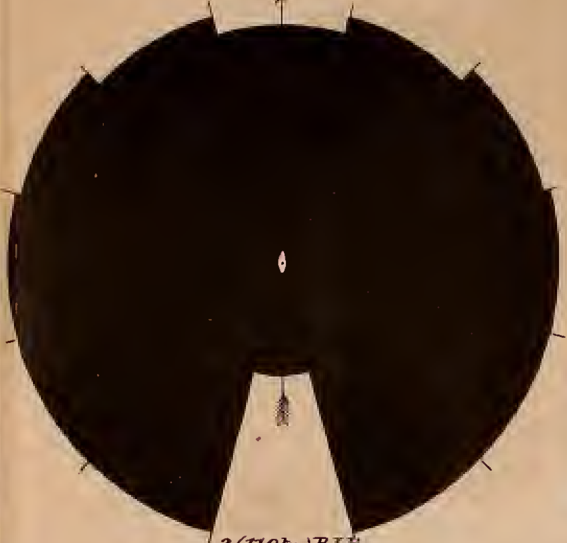
The principles which the diagrams seem to emphasize are, (1) that all guns should be mounted with unobstructed and large arcs of fire, and that to gain the utmost power from a mixed battery the heavy guns should command the greatest arcs. (2) That the most efficient and economical method of mounting the heavy guns is in pairs, on the middle line and as near the ends as is consistent with the structural arrange-

ITALIA
(13898 tons)



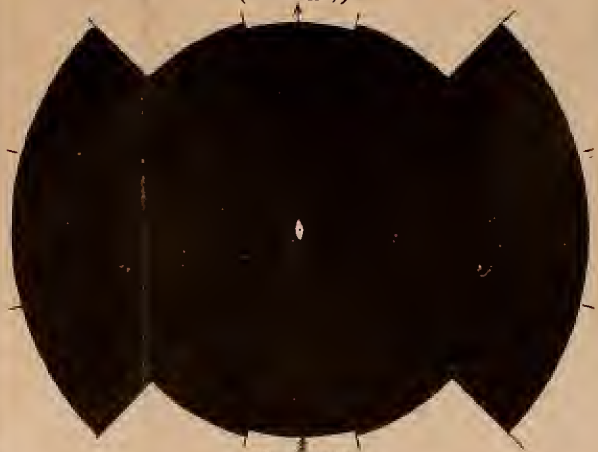
4 (106 ton) B.L.R.
8 (6") B.L.R.

RENOWN (Name changed to "VICTORIA")
(10500 tons)



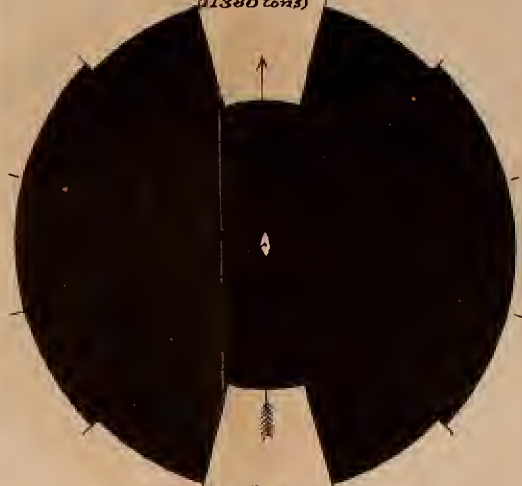
2 (110 ton) B.L.R.
12 (6") B.L.R.
1 (10") B.L.R.

NILE
(11940 tons)



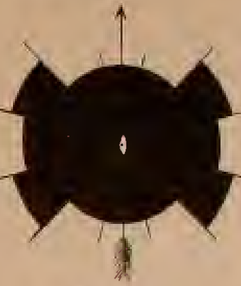
4 (13".5) B.L.R.
8 (6") B.L.R.

AMˡ BAUDIN
(11380 tons)



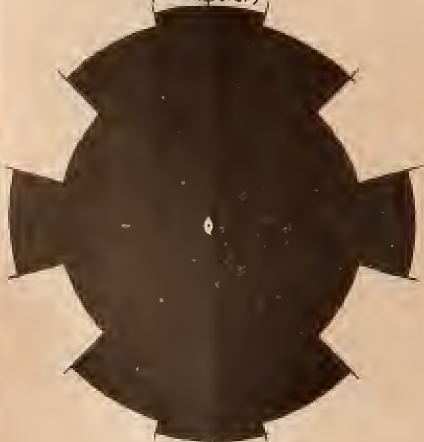
3 (16".5) B.L.R.
12 (5".5) B.L.R.

SUPERB
(10181 tons)



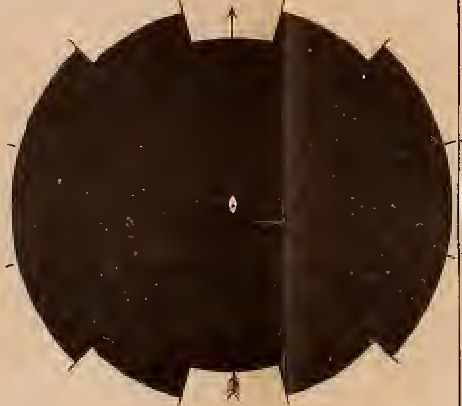
16 (10") M.L.R.
6 (4") B.L.R.

DÉVASTATION
(9639 tons)



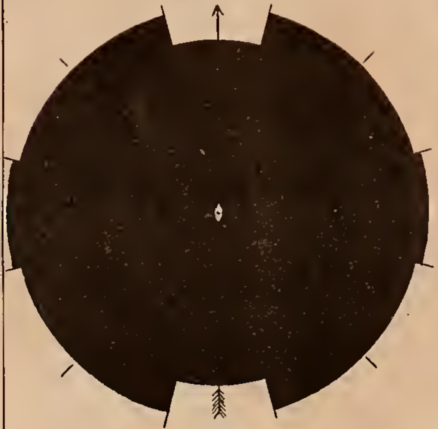
4 (13".4) B.L.R.
4 (10".6) B.L.R.
6 (5".5) B.L.R.

AMˡ DUPERRÉ
(10487 tons)



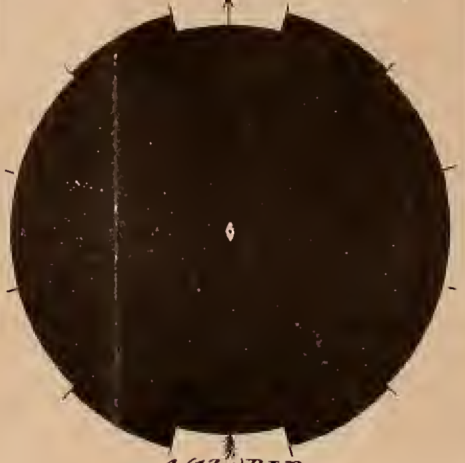
4 (13".4) B.L.R.
14 (5".5) B.L.R.

HOCHE
(10581 tons)



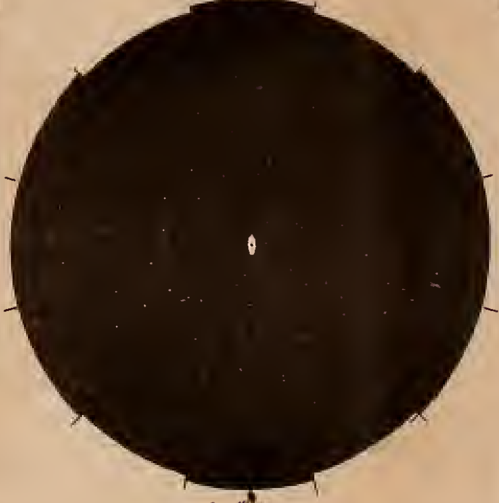
2 (13".4) B.L.R.
2 (10".6) B.L.R.
16 (5".5) B.L.R.

MAGENTA
(10581 tons)



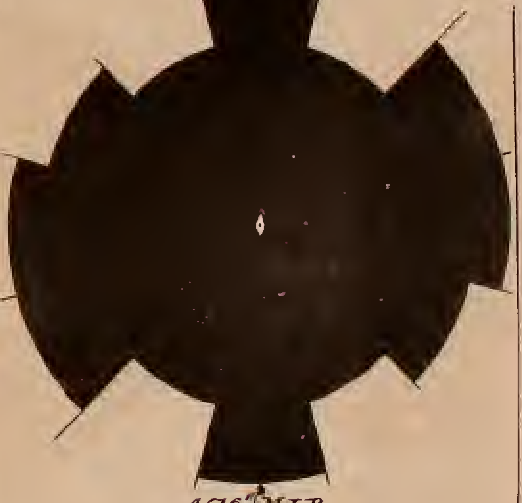
4 (13.4) B.L.R.
17 (5".5) B.L.R.

CATHERINE II
(10181 tons)



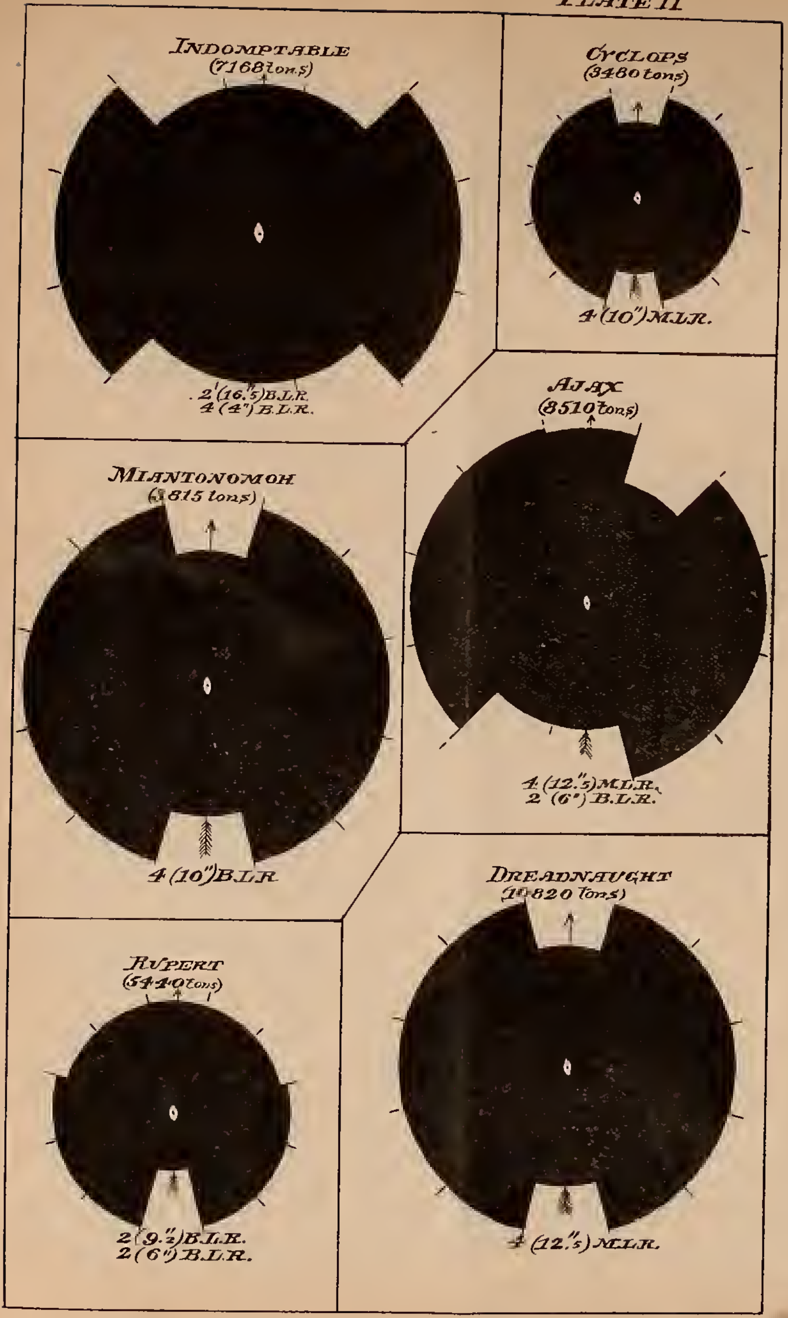
6 (12") B.L.R.
7 (6") B.L.R.

INFLEXIBLE
(11880 tons)

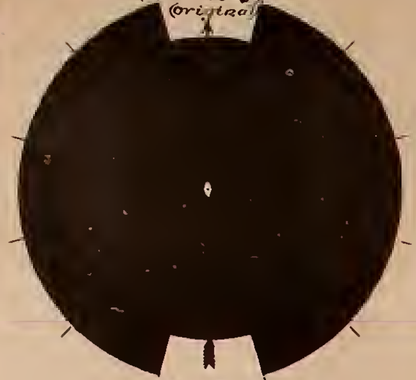


4 (16") M.L.R.
6 (4") B.L.R.
8 (20pr.) B.L.R.

PLATE II

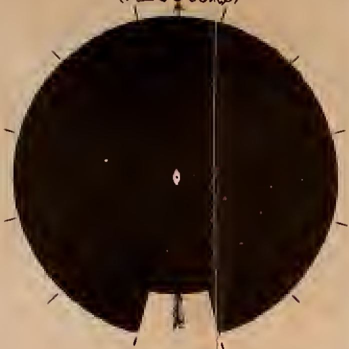

INDOMPTABLE
(7168 tons)
2 (16."5) B.L.R.
4 (4") B.L.R.
CYCLOPS
(3480 tons)
4 (10") M.L.R.
MIANTONOMOH
(3815 tons)
4 (10") B.L.R.
AJAX
(8510 tons)
4 (12."5) M.L.R.
2 (6") B.L.R.
RUPERT
(5440 tons)
2 (9."2) B.L.R.
2 (6") B.L.R.
DREADNAUGHT
(10820 tons)
4 (12."5) M.L.R.

ARMORED CRUISER
(6020 tons)
(original)



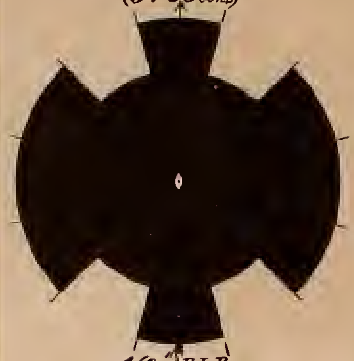
4 (10") B.L.R.
6 (6") B.L.R.

SACHSEN
(7400 tons)



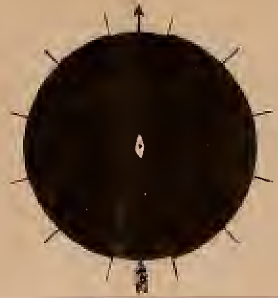
6 (10."25) B.L.R.

RIACHUELO
(5700 tons)



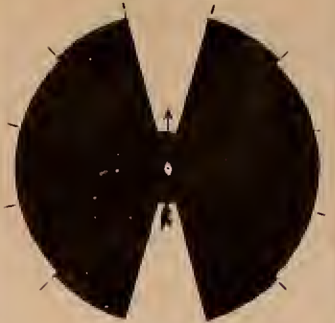
4 (9."2) B.L.R.
6 (5."5) B.L.R.

REINA REGENTE
(4800 tons)



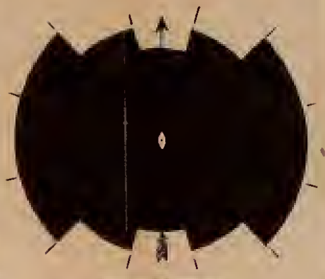
4 (9."2) B.L.R.
6 (4."7) B.L.R.

PREUSSEN
(6770 tons)



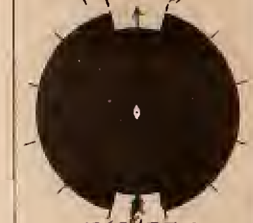
4 (10."24) B.L.R.
2 (6."7) B.L.R.

CHARLESTON
(3700 tons)



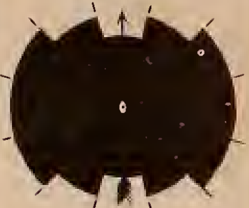
2 (10") R.L.R.
6 (6") B.L.R.

NEWARK
(4000 tons)



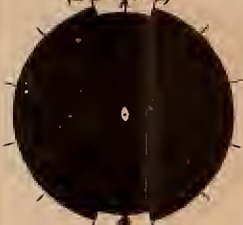
12 (6") B.L.R.

ATLANTA
(3300 tons)



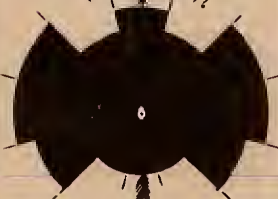
2 (8") B.L.R.
6 (6") B.L.R.

BALTIMORE
(4400 tons)



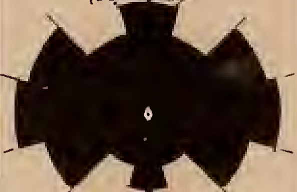
4 (8") B.L.R.
6 (6") B.L.R.

TEMERAIRE
(8540 tons)



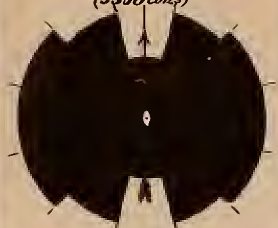
4 (11") M.L.R.
4 (10") M.L.R.
6 (20 pr.) B.L.R.

ALEXANDRA
(9490 tons)



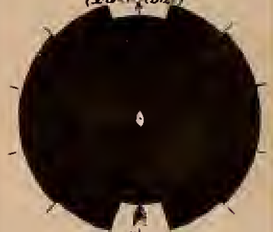
2 (11") M.L.R.
10 (10") M.L.R.
6 (4") B.L.R.

MERSEY
(3550 tons)



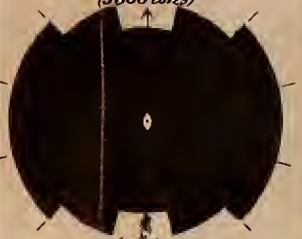
2 (8") B.L.R.
10 (6") B.L.R.

CHICAGO
(4500 tons)



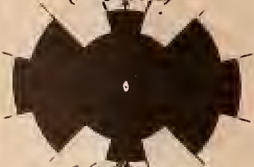
4 (8") B.L.R.
8 (6") B.L.R.
2 (5") B.L.R.

ORLANDO
(5000 tons)



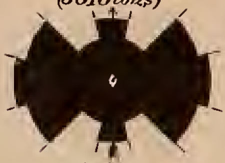
2 (9.2) B.L.R.
10 (6") B.L.R.

NELSON
(7630 tons)



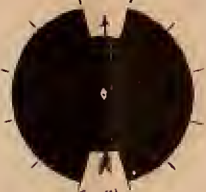
4 (10") M.L.R.
8 (9") M.L.R.

INVINCIBLE
(6010 tons)



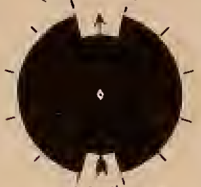
10 (9") M.L.R.
4 (64 pr.) M.L.R.
4 (20 pr.) B.L.R.

LEANDER
(3750 tons)



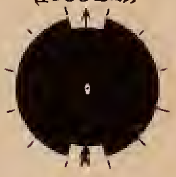
10 (6") B.L.R.

"IMPROVED ARCHER"
(1630 tons)



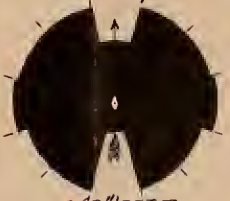
4 (6") B.L.R.

ARCHER
(1630 tons)



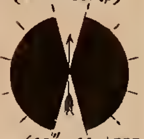
6 (6") B.L.R.

SHAH
(6250 tons)



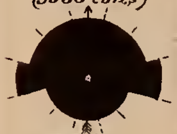
2 (9") M.L.R.
16 (7") M.L.R.
8 (64 pr.) M.L.R.

HUASCAR
(2100 tons)



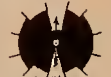
2 (10"-12½ ton) M.L.R.
2 (40 pr.) M.L.R.

ALMTE COCHRANE
(3500 tons)



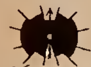
6 (9") M.L.R.

KEARSARGE
(1031 tons O.M.)



2 (11") S.B.
4 (32 pr.) S.B.
1 (30 pr.) M.L.R.

ALABAMA
(1016 tons O.M.)



1 (100 pr.) M.L.R.
1 (8") S.B.
6 (32 pr.) S.B.

ments and good behavior of the ship in a seaway. (3) That all sea-going war-ships should have four guns so mounted, and that the waist or broadside guns should be composed of the lighter calibres. In addition it may be added, without reference to the diagrams, (4) that all ships should supply the heavy guns with ammunition through tubes leading direct to them from the protected spaces in or about the magazine passages. (5) That all ships should be provided with all-around torpedo fire, if possible.

Torpedo tubes are guns in a certain sense, and a brief mention of their disposition will not be out of place here. They are best protected when placed under water, but when so placed they have no arcs of train, and it is only in large ships, and in ships specially designed for their use, that the necessary space can be found for them. Above-water tubes are more exposed to hostile fire, and we have yet to learn of the effect upon a ship produced by having one or more of her torpedoes prematurely exploded or jammed in the tube by hostile fire. Above-water tubes can usually be disposed to allow 90° of train to each tube, and if all-around fire can be obtained from 4 tubes, any more than that number above water would seem superfluous. If the internal arrangements of the ship permit, a good disposition of 4 above-water tubes would be, one on each bow and quarter with 90° of train and arranged to fire two ahead, two abeam, and two astern. In addition to the above-water tubes, most cruisers can be fitted, without much sacrifice of space, with one or two under-water tubes firing ahead in line with the keel.

VI.

RECENT PROGRESS IN SMALL ARMS.

By Lieut. W. H. Beehler, U. S. N.

The greatest activity prevails in Europe to provide better weapons for infantry. The question has not been confined to magazine and repeating rifles, but also includes consideration of calibre, mechanisms to utilize the recoil, the use of smokeless powder, and all the elements which may be of value in making the rifle most efficient.

This paper invites attention to the subject by brief descriptions of some of the rifles recently adopted or under consideration abroad.

The Proceedings of the United States Naval Institute, Vol. vii, No. 3, published in 1881, contains a paper by Lieut. W. W. Kimball, U. S. Navy, on magazine small arms, and also one by Mr. James P. Lee on the "Lee system." These clearly illustrate the nature of this question at that date.

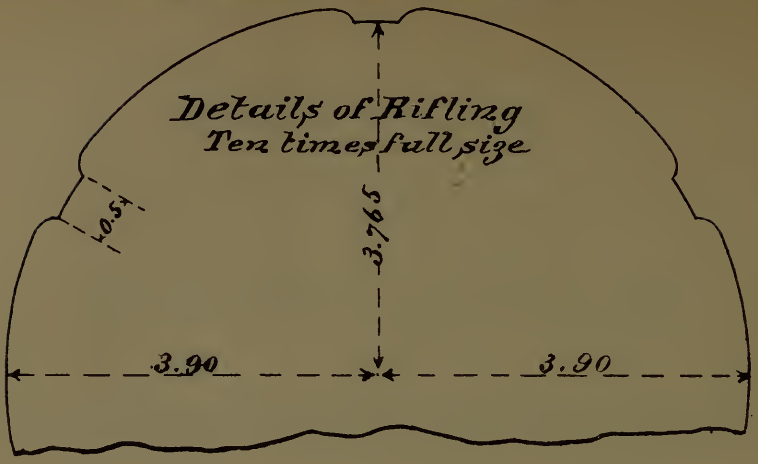
Capt. W. H. James discussed the merits of magazine and repeating rifles in a paper read before the Royal United Service Institution on February 25, 1887. He said:

> All forms of magazine can, as far as their position is concerned, be divided into four classes: (1) in the butt; (2) under the barrel; (3) over the barrel; (4) under the breech.
>
> No nation has adopted the first and third forms. Germany, France, Switzerland, Sweden, and Portugal have the second, with magazines under the barrel, in the systems of Mauser, Kropatschek, Vetterli, Jarmann, and Kropatschek-Guédes, respectively. These guns are all difficult to load, and the balance of the piece is altered each time the gun is fired.
>
> The chief objection to the first-class lies in the difficulty to load. The third class is objectionable because the aim is obstructed by the magazine over the barrel.
>
> The best position is that of the fourth class, with the magazine under the breech, as in the Mannlicher, Schulhoff, Pieri, Lee, and improved Lee. Austria has definitely adopted the Mannlicher.

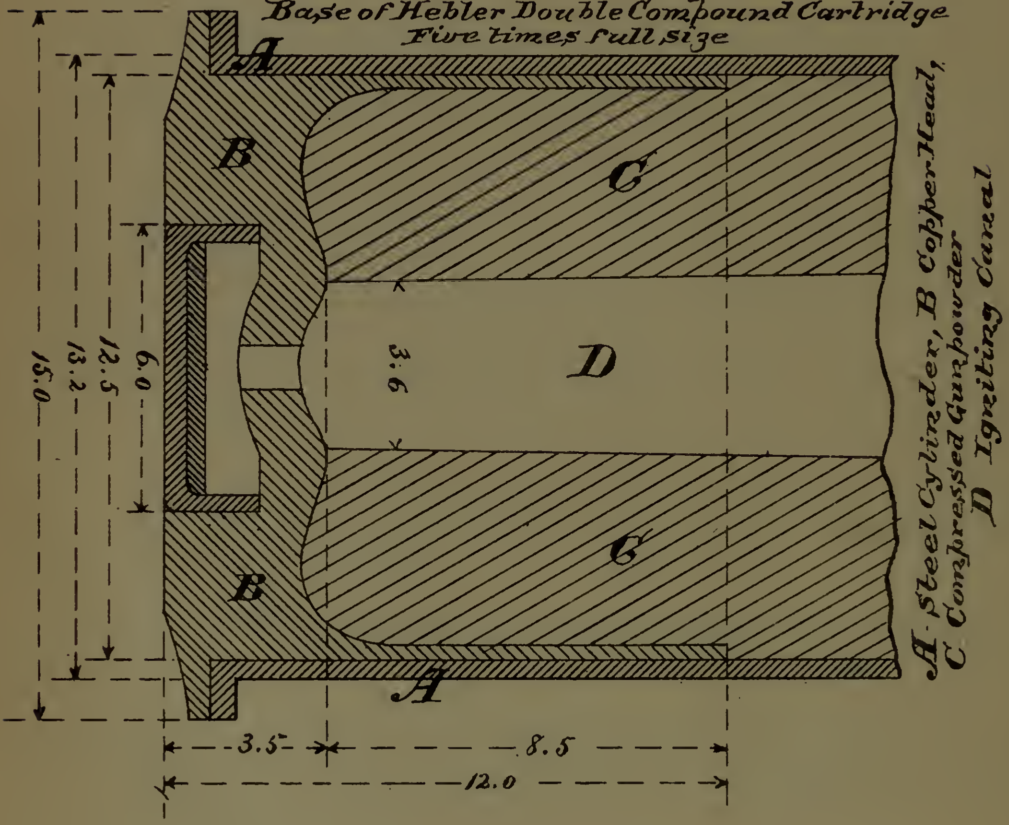
THE HEBLER SYSTEM.

The question of the calibre has been prominently brought forward by Professor Hebler, a German artillery scientist, in a pamphlet published at Leipzig last year, in which he explains the advantages of his system of rifling and those of the smallest practicable calibre. He claims a

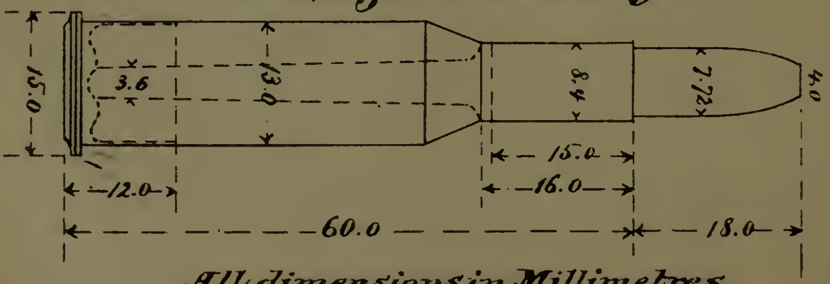
THE HEBLER SYSTEM


Details of Rifling
Ten times full size

Base of Hebler Double Compound Cartridge
Five times full size



Full Size of Cartridge



All dimensions in Millimetres

much flatter trajectory and thereby a much longer shot-swept space, less recoil, lighter ammunition, greater accuracy, greater penetration, less deviation by lateral effect of the wind, and that the wound produced is sufficient to cripple while much more humane.

He states that he has for years experimented with calibres of 8.7 to 7 millimetres, and finds the smallest size to be limited by difficulty in manufacture and subsequently to difficulty in cleaning. He finally selects a caliber of 7.53 millimetres (.296 inch).

He scientifically considers all features of rifling, twist, depth, and breadth of grooves and lands, the ammunition and the pressure of gases, and demonstrates, both mathematically and experimentally, that the most efficient rifle is one having a calibre of 7.53 millimetres, a uniform twist of one turn in 15½ calibres, and 6 grooves and lands concentric with the axis of the bore. The grooves should be 3.4 millimetres wide and 1.35 millimetres deep in the middle, while the lands should be but .5 millimetres wide. The diameter of the bore is therefore 7.53 millimetres between opposite lands and 7.8 millimetres between middle points of opposite grooves. He demonstrates the necessity of a very rapid twist in order that the bullet may not lose its spin and tumble before the end of its flight.

The Hebler cartridge consists of a bullet and a double compound cartridge case filled with a charge of compressed gunpowder. The bullet is made of 97 per cent. of lead with 3 per cent. of antimony. It is covered with thin sheet steel and nickel-plated. The double compound cartridge case consists of a thin cylindro-conical steel case open at both ends. The rear end contains a shallow copper case with a head forming the base; this head contains a central fire capsule and its periphery is arranged to expand on firing to form the gas check. The charge of powder is compressed in the case and has a central canal 3.6 millimetres (.14 inch) in diameter throughout its length, in order that the flame may instantaneously ignite the entire inner surface of the compressed charge. This facilitates the combustion of the powder, which would otherwise be very slow; because, when the powder is compressed, the air spaces between the grains are very much reduced. Both surfaces of the steel case are nickel plated in order to prevent rust. The bullet fits into the small end of the case and a space of one millimetre is left between the top of the powder and the base of the bullet. No paper covering is used. This cartridge gives an initial velocity of 600 metres (1968 feet) while the maximum gas pressure is but 7.32 tons per square inch.

The Hebler cartridge has the following dimensions:

	Inches.		Grams.
Length of bullet	1.32	Weight of case with capsule	13.7
Length of case	2.36	Weight of bullet	14.6
Depth of bullet in the case	.59	Weight of compressed charge	5.4
Total length of cartridge	3.07	Weight of grease	.1
Diameter of bullet	.304		
		Total (521 grains)	33,8

102 Hebler cartridges weigh the same as 80 Mauser cartridges.

Steel is used in the Hebler cartridge in preference to copper because it is stronger, less liable to be deformed, is four or five times cheaper, and does not form verdigris.

Professor Hebler demonstrates the reduction of the recoil in his system by mathematical calculations and comparisons with the recoil of other guns—the Mauser, Gras, and Martini-Henry. Comparative range tables are given with the Mauser and Hebler rifles, in which the ordinates of the trajectory, length of shot-swept space, penetration, and accuracy are clearly shown, and in which Professor Hebler demonstrates great superiority of the Hebler rifle. The penetration of the Hebler rifle in fir wood is 100 centimetres (39.4 inches) at the muzzle, and 7 centimetres (2¾ inches) at a range of 2,500 metres; while the penetration of the Mauser rifle is 24 centimetres (9.5 inches) at the muzzle, and but 5.5 centimetres (2.16 inches) at its maximum range of 1,600 metres. The penetration into iron is .4 inch with the Hebler, and .26 of an inch with the Mauser.

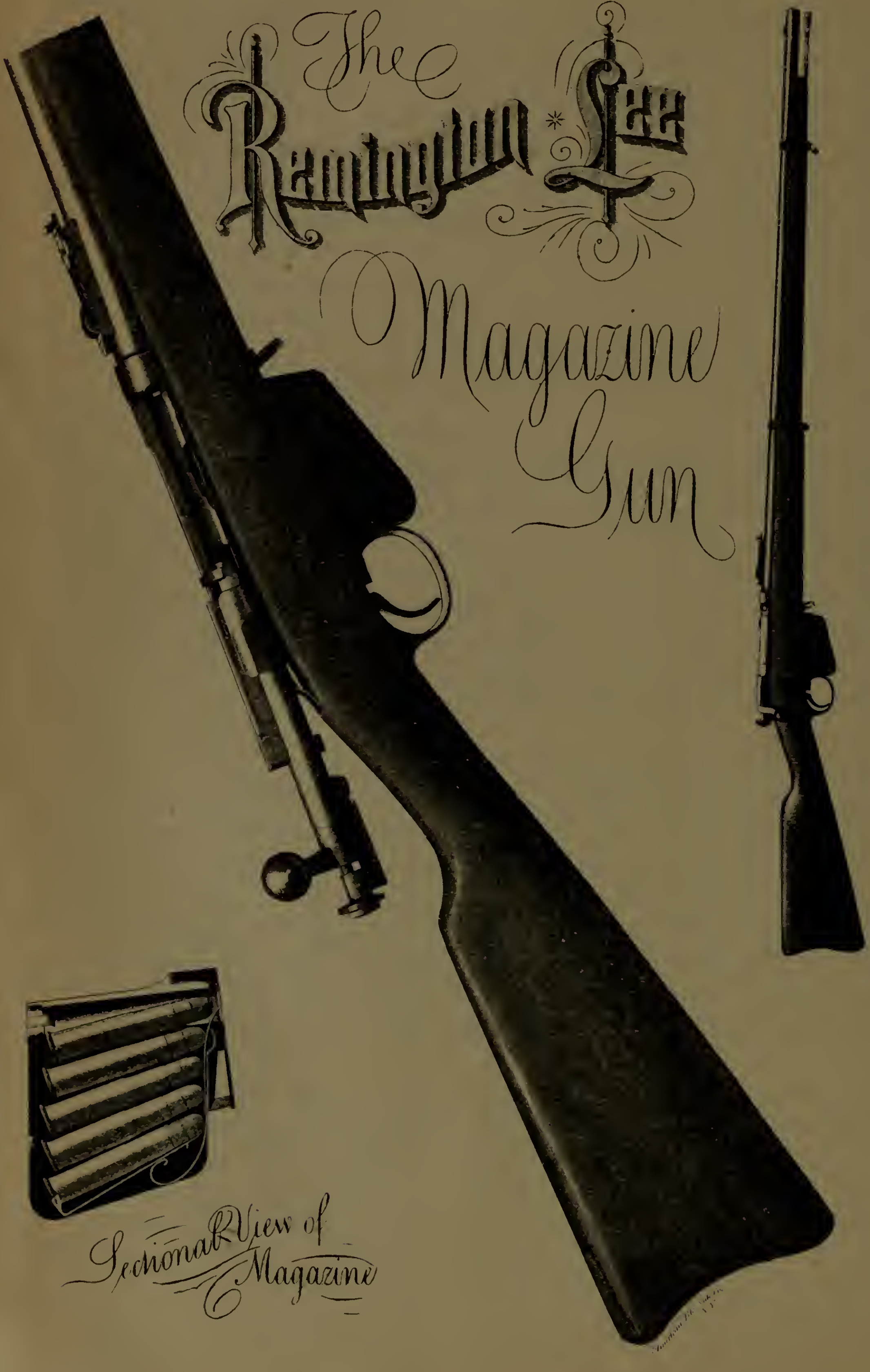
Experiments on animals demonstrated that the wound caused by Hebler bullet was much less serious than that from others. The Hebler bullet makes a clean hole, while others make ragged and splintered holes, so that even if vital parts are not struck the wound made remains serious for years. In one case a man shot by Hebler bullet in upper left arm entirely recovered in three months, though he was hors de combat for two months. It is more advantageous to wound than to kill. A dead man requires burial only; a wounded man needs the assistance of two others, is an additional expense to the state, and can render no service for a long time.

Some of the special features of the Hebler rifle are being adopted in the Chalons rifle, for the fabrication of which the French legislature recently appropriated large sums of money. Le Progrés Militaire of March 30, 1887, gives some particulars about this gun, known as the Lobell rifle. It has a calibre of 8 millimetres (.315 inch), and uses a smokeless powder, by which an initial velocity of 620 metres (2,034 feet) is obtained, instead of 1,430 feet, the initial velocity of the Gras rifle.

The Rivista di Artiglieria é Genio, of November, 1886, states that 10,000 of these Lobell magazine rifles were then being manufactured in France, at Tulle.

The French newspaper account gives no definite particulars about the mechanism of this gun, but is very enthusiastic over the advantages of using smokeless powder. The composition of this powder is not given, though smokeless powder has been in use for years. It is probably a gun-cotton powder similar to that produced at Waltham Abbey, England, in 1881; or a white intrated-wood powder.

There is no official authority to confirm these statements about the French rifle, nor is the method described by which this powder is made suitable for military uses.



The Remington-Lee Magazine Gun

Sectional View of Magazine

The question of the value of the magazine rifle is discussed in detail by Captain James, and its opponents claim that the advantages are completely counterbalanced by the difficulty of supplying the enormous expenditure of ammunition. It will be necessary to have a perfect fire discipline to prevent waste of ammunition, and the magazine rifle should, by its mechanism, contribute to the control of the expenditure of the ammunition.

Lieutenant Kimball, U. S. N., is of the opinion that the magazine system should be such as to give company officers some clear evidence of readiness to deliver magazine fire; and this can be best secured by some practical form of detachable magazine, which will not permit the arm to be used as a single loader while it is in place upon the piece.

THE REMINGTON-LEE MAGAZINE RIFLE, 1887.

The improved Lee or Remington-Lee has a detachable magazine, and is also arranged to be used as a single loader with the magazine either attached or detached. The mechanism which permits the gun to be used as a single loader, while the magazine is still attached, is not without its disadvantage, for one of the chief advantages of a detachable magazine consists in giving officers visible evidence of the manner in which the gun is being used.

The Remington-Lee is a bolt gun with an opening through the bottom of the receiver for a detachable magazine, which fits into the opening and is held there by a spring catch which engages a detent in the rear face of the magazine case. A portion of this spring catch projects through the bottom of the stock within the space inclosed by the trigger guard. This is just in front of the trigger; by the upward pressure of the finger of the right hand the spring catch is disengaged and forces the magazine out. This is a recent improvement, as it was formerly necessary to pull the magazine case out by hand.

The Remington-Lee magazine case has but one spring to feed the cartridges up into the receiver. One end of this flat spring is secured to the upper forward end of the magazine case; the other end bears against the under surface of the follower, which is held down by the weight of the superincumbent cartridges. When empty, the follower lies across the top of the magazine case.

The gun has a recess cut in the inner face of the receiver, into which is fitted a curved sliding plate, which is capable of being pushed around in the recess so as to lie across the slot in the bottom of the receiver when the arm is to be used as a single loader. When the magazine case is pushed completely home in the receiver this curved sliding plate is thereby pushed back to uncover the slot and admit a cartridge from the magazine. If the magazine is not pushed home it will be held in the opening by the spring catch, but the sliding plate will cover the slot in the receiver and permit the gun to be used as a single loader.

The improved magazine case has an arrangement of inner projecting ribs and lips on the follower to hold cartridges at the proper angle and to dispense with the overhang and retaining device used in the old Lee magazine. Cartridges are thereby prevented from jumping too high when fed into the receiver, and this also serves to retain cartridges in the magazine if it be thrown down on the ground. The new magazine case is made of one piece of steel with sleeves slipped on at the rear, forming the rib. It contains five cartridges, and upon one being emptied a full one can be substituted by a fairly trained soldier in two seconds. All liability to explosion in the magazine is obviated by this system, which is not the case with tubular magazines. This magazine is attached so near to the centre of gravity of the gun that the balance of the arm is not affected by attaching or emptying the magazine.

The bolt mechanism is similar to that of other bolt guns. The bolt handle in the Remington-Lee is at the rear end of the bolt instead of near the middle, as in the old Lee; thus providing an efficient means for delivering magazine fire without bringing the piece down from the shoulder between shots. The rear end is also made more solid by having the firing pin inserted from the front instead of from the rear.

THE AUSTRIAN MANNLICHER RIFLE.

Austria has definitely adopted one of the many varieties of the magazine rifles invented by F. Mannlicher, an Austrian civil engineer. This gun has a detachable magazine, and the manipulation of the breech-bolt simply requires a straight backward and forward motion so that the gun can be fired and loaded without removing the piece from the shoulder in position of " aim " until magazine is emptied.

The breech-bolt mechanism is similar to that of the Vetterli system, in which the bolt is cocked by turning the bolt lugs through an arc of 90°, with this difference that, instead of turning the bolt handle, the same effect is obtained by action of independently moving parts of the bolt, so that a straight backward and forward motion only is necessary.

The cartridges are carried packed in the magazine cases, each holding five cartridges. These are placed in a receptacle from underneath the receiver, fitted to take and retain the magazine case. The receptacle is merely a hollow frame with bent rocking levers, which project into the tin magazine case when attached. The ends of the levers enter from the rear and below, to operate as a carrier for the cartridges, and successively feeds them into the receiver space. The breech-bolt in moving back and forth acts by a shoulder on the upper arm of the bent rocking lever to operate the successive feed into the receiver space.

The tin magazine case weighs 385 grains, the same as a bullet, and costs about 2 cents. It is simply a small tin box with its top open and upper edges bent over to form lips, by which it is hung in the receptacle frame in the gun. It has slots in the bottom and in its rear face for the rocking levers or carrier. The cartridges lie over each other horizontally with bullet ends in front. A side spring holds the case in the vertical plane directly under the receiver, clear to feed. When this spring is pressed by the thumb the lips are disengaged and magazine case drops out and is thrown away. The receptacle frame is then clear for another magazine.

All the ammunition is carried packed in the magazine cases and two cases are wrapped together in paper to prevent injury in transportation.

The rifle is designed to be used as a magazine gun only, and as at present made cannot be used as a single loader; though in practice it is not necessary for the soldiers to fire more than one round at a time. The mechanism does not contribute to assist in the control of the expenditure of ammunition.

THE GERMAN MAGAZINE RIFLE, M., 71–84.

During the past year Germany has re-armed her infantry with a magazine rifle converted from the Mauser breech-loading rifle M. 71. This is designated as the infantry rifle M. 71–84, calibre 43.

It consists of the following parts, viz, the barrel, breech mechanism, stock, and garniture.

The barrel is made of mild cast steel, cylindrical, slightly diminishing in thickness at the muzzle, and has an octagonal shape in rear of the rear sight, while that portion of the barrel forward of the rear sight is round and smooth.

The muzzle sight is a hardened steel knife-edge, sloping towards the muzzle, and is pushed into the notch of the sight-mass sideways.

The rear sight consists of two hinged sight-bars secured to the sight-mass by a movable pin, the small bar in rear and long bar in front. Both bars are brought into vertical position for use by pressure of the finger, the small bar being held in position by a spiral spring in the right eyelet and the long bar by a spiral spring set in the foot of the sight.

The long bar has the shape of a parallelogram, with lines marked on both sides, and with numbers on the left side indicating distances, viz, 4=400 metres, 5=500, and so on up to 1,600 metres. The lines on the right side indicate distances between those, as 450, 550, up to 1,450 metres. A leaf slides on the long bar, which may be placed opposite the marks and held there by a clasp.

When the long bar is down the standing sight is in position, and it is used for distances less than 270 metres. The small bar serves for 350 metres; the long bar for distances of 400 to 1,600 metres. There is a small stop notch on the upper part of the left side of the bar, which prevents the leaf from sliding off, and at the same time serves to mark the sight for 1,500 metres. There is no mark for 1,550 metres, and that for 1,600 is in the top of the bar. The centre of the top edge of the bar and of the leaf have small triangular notches, through which the line of sight passes over the muzzle sight to the target. The sights are kept dark dull to avoid any errors in the aim by deceptive light.

The rear end of the barrel is closed by the breech bolt. The bore is divided into two parts, the rifled portion and the cartridge chamber.

The rifling consists of four grooves and four lands of equal breadth. The twist is from left to right, and makes one turn in 50 calibres. The calibre is 11 millimetres (.43 inch), and is uniform from the chamber to the muzzle. The lands are beveled, sloping towards the chamber, to permit the cartridges to take the rifling with facility. The chamber is in the octagonal part of the barrel; its walls are smooth and very strong.

The rifle is 1.3 metres (4 feet 3 inches) long, and with the bayonet is 1.8 metres (5 feet 11 inches) long. When empty it weighs 4.6 kilograms, and loaded 5 kilograms (11 pounds). The bayonet weighs 800 grams (1.76 pounds).

The centre of gravity is from 22.4 to 26.4 inches from the butt, depending upon the condition of the magazine, whether empty or loaded. If the bayonet is fixed the centre of gravity is .4 inch further forward.

The breech mechanism.—This is made of steel and consists of the following parts:

(1) The case.
(2) The breech-bolt proper.
(3) The trigger mechanism.
(4) The repeater-loading mechanism.

(1) The case contains the breech-bolt proper. A screw thread on its forward end engages the thread on the base of the barrel. It has an opening which forms the cartridge receiver, in the bottom of which there is a spoon or carrier for cartridges. There is a grooved recess for the ejector and a rectangular hole for the stud of the cut-off spring. The extractor works in a grooved slot to the right and above. The bolt-slide has an abutment for the shoulder on the bolt, and in the bottom there is a groove for the lip of the breech plug and an oval hole for the trigger tumbler. The case is secured to the wooden stock by screws in the bottom of the case head and the tang screw.

(2) The breech-bolt proper fits in the case and works back and forth in the bolt-slide.

It consists of the following parts:

(*a*) The bolt with guide rail and knob handle. Its rear end has a triangular shape to fit over corresponding triangular extremity of the forward end of the breech plug.

(*b*) The firing pin and spring.

(*c*) The small breech plug with triangular end to fit into corresponding triangular ends of the bolt.

(*d*) The safety piece and spring.

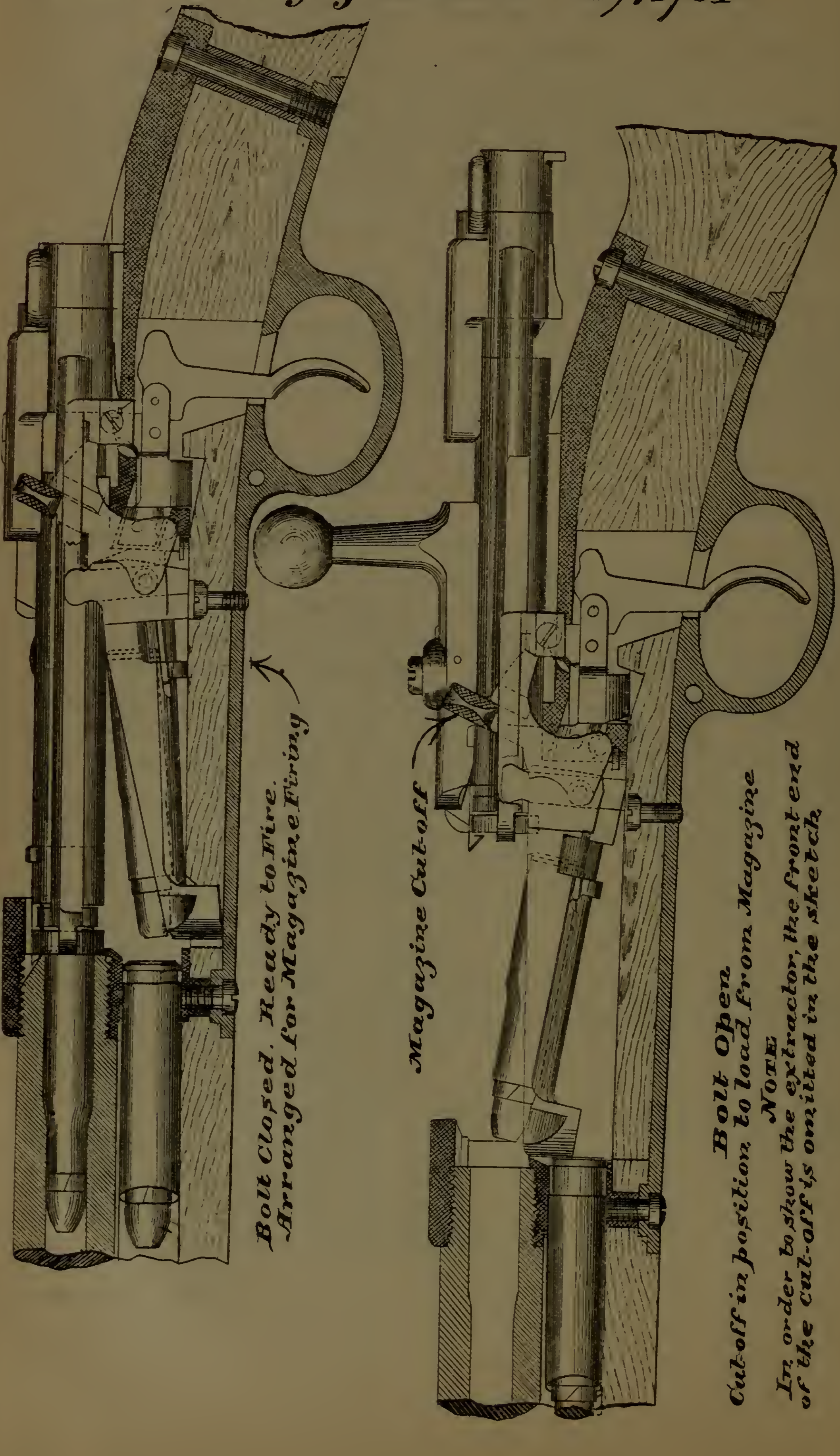
(*e*) The screw nut of the firing pin.

(*f*) The head piece of the breech bolt.

(*g*) The extractor.

(*h*) The ejector.

German
Mauser Magazine Rifle M/71/84



Bolt Closed. Ready to Fire.
Arranged for Magazine Firing

Bolt Open
Cut-off in position to load from Magazine

NOTE
In order to show the extractor, the front end of the cut-off is omitted in the sketch.

The firing pin is screwed into the breech plug and goes through the bolt with its forward pointed end projecting through the bolt head piece. The spiral firing-pin spring is coiled around the pin in the bolt proper.

The bolt's guide-rail has a shoulder which fits into the abutment in the case and prevents the bolt from falling out of the case when drawn back and open. By loosening the screw the bolt may be drawn over.

The breech is closed by the head piece of the bolt, which is free to revolve in the recess in the front end of the bolt; it is bored to admit the firing pin.

The safety piece prevents the gun from being fired accidentally. This fits into the guide rail of the breech plug and is free to revolve; when turned to the right (if the breech is closed and cocked) it engages a notch in the plug so that the breech plug cannot fly forward even if the trigger be pulled. Besides, it is then impossible to turn the bolt and open the breech. The safety piece is disengaged by turning it to the left. Its spiral spring serves to hold it and make it work smoothly.

The extractor fits on the head piece and has a claw by which it draws the empty cartridge case out of the chamber as the bolt moves to the rear.

The ejector is a long semi-cylindrical piece of steel which fits under the bolt, and when the bolt is drawn back to its full extent it throws out the extracted cartridge case. It also operates in connection with the magazine cut-off to work the repeater-loading mechanism.

(3) The trigger mechanism is secured under the case and consists of the trigger, trigger fork with spiral spring, the trigger spring, and the trigger tumbler, which fits into the oval hole in the case. The mechanism is such that a gradual pull on the trigger finally disengages the tumbler which permits the breech plug to fly forward and makes the end of the firing pin strike and explode the cartridge.

(4) The repeater loading mechanism consists of the cartridge magazine, the pawl with double spring, the spoon or carrier, and the cut-off.

The magazine is a tube of thin sheet steel placed in a hole bored in the wooden stock. Its rear end opens into the case and its front end has a cover to which a stick is attached to enable arms to be stacked. It contains 8 cartridges and a spiral spring with a disc on the rear end; the spring presses the cartridges towards the opening into the case. The pawl prevents the admission of a second cartridge, or of the disc on the end of the spring, into the spoon.

The pawl is secured to the left side of the bottom of the case and projects with its claw through to the opening of the magazine tube. Its double spring is screwed to the case and holds it in place.

The spoon or carrier is a hinged block with a hollow surface to fit the cartridges; it is secured to the case so that its front end may rise and fall. A groove is cut in the left side of the spoon's shoulder to receive the cut-off by which it is raised or lowered. When the pawl is drawn back and the spoon depressed, a cartridge is admitted from the magazine.

The cut-off or regulating mechanism serves to adjust the gun for a repeater or single loader. It consists of the cut-off lever and its spring. It has a button which projects through the case and by which the cut-off lever may be placed in one of three positions—forward, middle, and rear positions. When the cut-off is in the forward position, the gun is regulated to work as a single loader; when in the rear position it allows the repeater-loading mechanism to work, and when in the middle position the bolt mechanism may be taken apart.

When in the forward position, a stud on the cut-off spring lies in the recess of the ejector, and the forward end of the spoon is held up by the lever spring, so that the piece is adjusted as a single loader.

When in the rear position, the stud on the cut-off spring bears against the forward side of the shoulder of the spoon, which is thereby pressed down, while the pawl is drawn back and a cartridge is admitted from the magazine.

The position of the cut-off can only be changed to that of the middle position when the breech is closed. To change the cut-off from the forward to the rear position, or *vice versa*, the breech bolt must be open and the spoon up.

Detailed operations of the breech mechanism.—1. The breech closed after having fired the gun.—In this position the head piece of the breech bolt is in contact with the base of the cartridge, the claw of the extractor engages the upper rim of the cartridge case, and the firing pin projects through to contact with the centre of the capsule. The breech plug fits close into the triangular extremity of the rear end of the bolt, and its nose has passed over the trigger tumbler. If the cut-off is in the forward position the gun is adjusted as a single loader, and the spoon is held with its forward end raised and cannot move. If the cut-off is in the rear position the spoon is pressed down and a second cartridge is admitted from the magazine.

2. To open and draw back the bolt to load.—The bolt handle is turned to the left and its guide rail moves between the curved surfaces and clears the opening of the receiver. Other parts of the bolt do not turn with it; the breech plug, with firing-pin and nut, is held by its guide rail, which fits in the groove in the case, and the head piece is held by the ejector. When the bolt turns, the breech plug is pushed to the rear as the triangular surfaces disengage. While the breech plug is forced to the rear it pulls back the firing-pin with its spring, which is thus compressed equal to the length of the triangular projection on the bolt; at the same time the nose of the breech plug glides over the trigger tumbler with a distinct click.

The bolt is now drawn back and all parts follow its rearward motion until the receiver is cleared. The extractor draws the empty cartridge case into the receiver, and when the bolt is back the ejector strikes the cartridge case and throws it out of the receiver. If the cut-off is in the rear position the stud on its spring no longer holds up the ejector, which therefore bears upon the rear side of the spoon shoulder and raises the spoon while the bolt moves to the rear. The cartridge which had been admitted into the spoon from the magazine is thus fed into the receiver.

If the cut-off is in the forward position the ejector simply throws out the empty cartridge case, and the spoon being already raised it is in position for a single loader.

3. To load and close the breech.—If the gun is adjusted as a single loader the cartridge is placed in the receiver by hand. If adjusted for a repeater a cartridge will have been admitted into the receiver as described. The bolt is then pushed forward and enters the cartridge into the chamber, while the breech plug approaches so that its notch is fair to take on the trigger tumbler. The bolt handle is then turned to the right until the guide rails are in the same plane, that is, to the full extent to which the bolt may be turned. The breech plug is held back by the trigger tumbler with its triangular extremity fair to fit into the corresponding triangular end of the bolt. The head piece is the position described in 1, and the firing-pin, with its compressed spring, is held back by the breech plug retained by trigger tumbler.

The gun is loaded and full cocked. If the trigger is pulled the breech plug is released and the firing-pin is forced forward to strike and explode the cartridge.

The garniture.—This serves to bind the stock with other parts of the gun and is done by 3 bands, 1 band spring and screw, 1 upper band spring and screw, 2 band studs, 1 binding screw, 1 tang screw and tube, 1 trigger plate with screw and trigger guard, and a butt plate with 2 screws to prevent injury to the bottom of the stock. Besides these, there are other appurtenances, such as the slings and its rings, cleaning rods, muzzle cover, and sight cover. One screw-driver is issued with 10 guns.

The ammunition.—There are three kinds of ammunition, viz, the service, blank, and exercise cartridges. The service cartridge consists of a brass case containing 5 grams (77 grains) of gunpowder, with the ordinary central-fire capsule. The powder charge is covered by two folds of cartridge paper and a drop of wax. The bullet is of lead and antimony, as generally used, and weighs 25 grams (386 grains). Its cylindrical portion is provided with a paper wrapper.

The blank cartridge of M. 71 consists of a case and capsule. The case contains 3.5 grams (54 grains) of inferior powder and 2 paper wads without projectile. The blank cartridge of M. 71–84 is intended for magazine firing. It has but one paper wad and a hollow wooden bullet painted red. It has the same size and shape of the service cartridge.

The exercise cartridge contains no powder, but is of the same shape and size of the service cartridge. It consists of a brass case, brass cone lining, gum cylinder, and pistol.

The service cartridge weighs 43 grams (663 grains) and is 78 millimetres (3.07 inches) long. This cartridge is the same as that used in the single loader. Experiments have recently been made with an improved cartridge containing 89½ grains of gunpowder and a steel-covered bullet. This cartridge gives a higher initial velocity, greater penetration, and flatter trajectory.

SYSTEMS UTILIZING THE RECOIL.

Maxim Recoil Repeating Rifle.

Mr. Hiram S. Maxim originated methods for utilizing the recoil and applied the principles to a machine gun, in which the force of the recoil is caused to operate mechanism to load and fire successive shots automatically. Mr. Maxim does not restrict his invention to machine guns, but also applies the same principle to small arms.

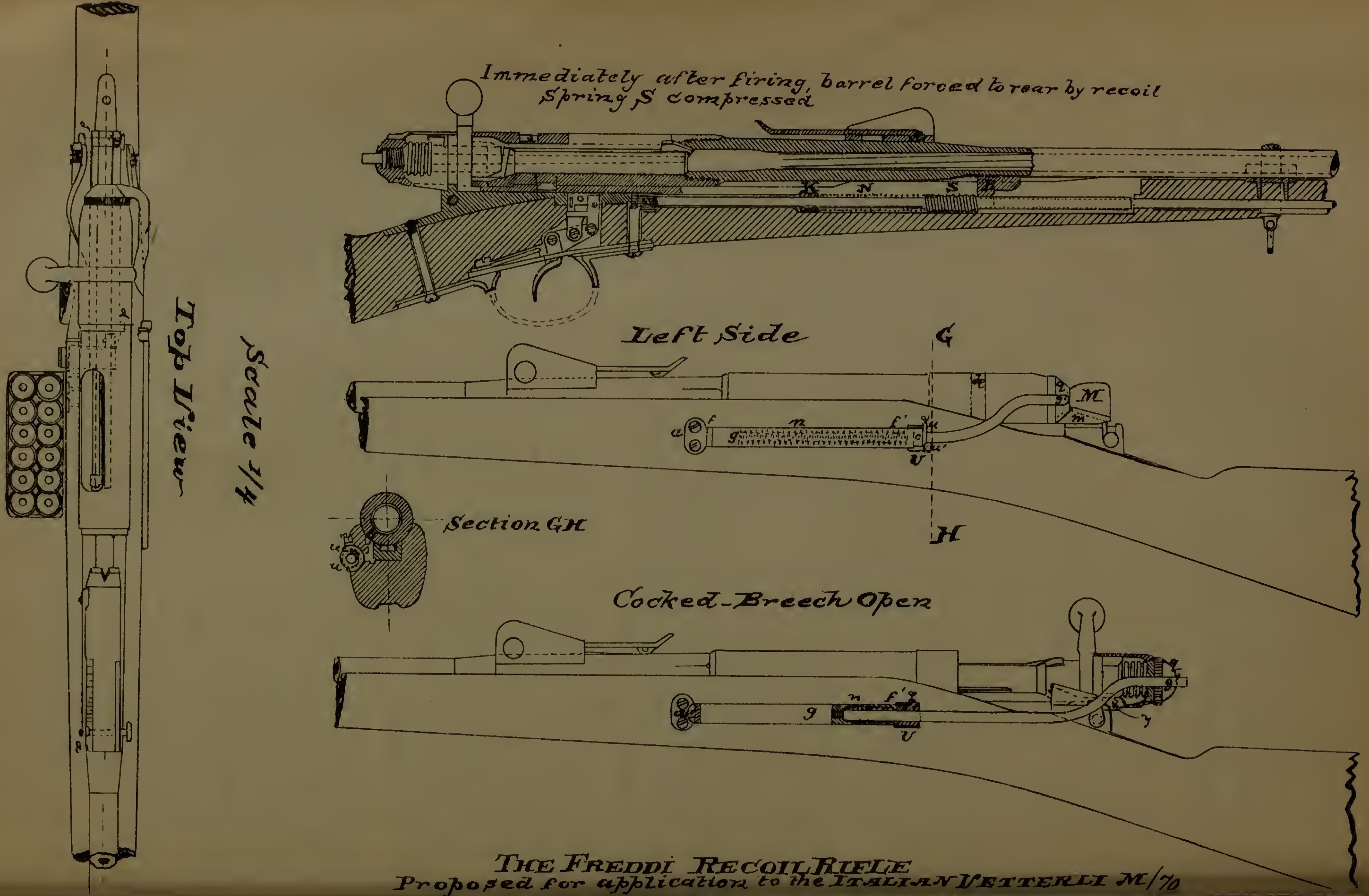
In the Maxim modification of the Winchester magazine rifle the operation of feeding from the magazine by working the guard plate by hand is substituted by working levers attached to the guard plate. These levers are connected with the butt plate by rods and springs in the butt stock, so that the force of the recoil brings the butt plate, which is normally about an inch from the butt, close up to the butt; the springs are thereby compressed and the guard plate is alternately pushed back and forth to work the feeding mechanism. The magazine is tubular and located under the barrel.

An improved Maxim recoil repeating rifle receives the force of the recoil on the breech block direct; the breech block is thereby forced to the rear and compresses a strong spiral spring. In moving to the rear the breech block extracts the empty cartridge case and a system of levers work a revolving drum under the receiver to supply a new cartridge. The compressed spring then forces the breech block forward to push cartridge into the chamber and close the breech. If the trigger is held back the firing pin will be released to fire the cartridge.

The revolving drum has eight sectors in which the breech block moves back and forth successively as the drum revolves. When completely loaded there will be one cartridge in the chamber and seven cartridges in the drum, the eighth sector being occupied by the breech block. All eight cartridges will be successively fired by pulling the trigger once and holding it back. If the trigger be released, immediately after firing, single shots may be fired until magazine is emptied.

The breech block is movable by hand and the drum must be loaded by inserting cartridges by hand and turning the drum until the seven sectors are loaded and one cartridge entered into the chamber.

By working the movable breech block by hand the gun may also be used as a single loader.



THE FREDDI RECOIL RIFLE
Proposed for application to the ITALIAN VETTERLI M/70

Paulson Recoil Repeating Rifle.

In the Paulson system the gases due to the explosion are allowed to enter a small aperture in the barrel at a suitable distance in front of the chamber. This pressure operates to unlock a long, bent rod, the rear end of which is vertical and holds the breech block in place. The pressure of the gases carries the long, bent rod to the rear and this draws the breech block down and to the rear to open the receiver. A strong spiral spring on the long, bent rod is compressed by the rearward motion of the rod, which reacts to replace the breech block and the long, bent rod. The gun is reloaded by hand while the breech block is down and the receiver open. The Paulson system provides for repeating mechanism by means of a detachable magazine attached to the side. This mechanism is worked by the pressure on springs, as the breech block opens the receiver, so that cartridges are fed from above into the receiver.

Freddi Recoil Rifle.

Captain Freddi, of the Italian army, has invented a method for converting single-fire into quick-firing rifles by utilizing the recoil to open the breech bolt, with springs to open and close the breech.

The rear end of the barrel has a spiral spring ("S") attached, which works in a tube ("K") below the breech bolt. When the gun is fired the recoil acts on the barrel to carry it to the rear for a distance of 7 centimetres (2¾ inches); the spiral spring is thereby compressed and the breech-bolt is also carried to the rear to the same distance. While the barrel recoils the charge of powder is consumed and the bullet leaves the gun. When the force of the recoil is expended the spiral spring reacts to throw the barrel forward again, but the breech bolt is caught and held to the rear by a detent mechanism ("M"). The cartridge receiver is thus left open and the soldier introduces a new cartridge by hand. He then grasps the piece so that his finger is in contact with a button ("δ") on rear end of the bolt, which when pressed releases the breech bolt, which is then, by another spring (*n*), forced to fly forward to close the breech. The trigger mechanism cocks the firing pin as the bolt first moves to the rear, and pressure on the trigger releases firing pin to strike and explode the cartridge. (See figure.)

In this manner the operation of moving the breech bolt back and forth by hand is done by the recoil movement of the barrel and action of springs, one spring acting immediately to replace the barrel and the other acting upon being released when the button is pressed after a new cartridge is introduced by hand.

All the operations usually performed by moving the bolt, such as throwing out empty cartridge case and cocking, are also done in this system, except that the recoil and action of springs substitute the action by hand.

The piece is loaded by inserting a cartridge in the receiver as in the ordinary single loaders. Captain Freddi has provided for still further rapidity of fire by attaching leather cartridge-boxes containing twelve cartridges in two rows of six each to a hook on the side of the barrel. By this arrangement the soldier can keep his rifle in the position of "aim" and take a cartridge from the cartridge-box, insert it in the receiver, press the button of the bolt-spring and pull the trigger with fore-finger, and repeat the operation without removing the gun from the shoulder until the twelve cartridges have been fired. When the leather cartridge box is empty the soldier brings his piece down to position of "ready" and attaches another box.

This rifle may be fired twenty-four times in one minute, including the time necessary to attach and change cartridge boxes. The first twelve shots may be fired in twenty seconds.

In case the recoil barrel spring breaks, or if there be any other defect, the soldier can use the gun as an ordinary single loader by introducing a wedge piece and working the bolt by hand.

The advantages claimed for this system are:

(1) Reduction of the weight of gun. In ordinary rifles it is necessary to make the gun heavy, in order that the soldier may support the shock of the recoil. In this system the force of the recoil is utilized, and the weight which is otherwise necessary will enable the soldier to carry a greater number of cartridges, equivalent to the saving in the weight of the rifle.

(2) Flatness of trajectory. The chief obstacle in the way of obtaining this quality lies in the recoil; for, if we call the weight of the gun P, the weight of the bullet p, the initial velocity V, and the velocity of the recoil v, we have:

$$P\ v. = p\ V \text{ or } v = \frac{p\ V}{P}.$$

That is, the velocity of the recoil varies inversely as the weight of the gun and directly as the product p V, upon which depends the flatness of the trajectory. If the velocity of the recoil is excessive the soldier can not support the fatigue, either in rapid or in ordinary firing, and the weight of the gun must not exceed a certain limit to be portable and easily managed. By utilizing the recoil the gun may be lighter and the bullet may be given greater initial velocity.

(3) Rapidity of fire by means of the mechanism which obviates all movement of the breech bolt by hand, and by attaching cartridge boxes convenient to load when in the position of aiming without removing the piece.

The idea of attaching a cartridge box to the gun is not new. In this system the leather box is attached to a hook on the right side of the piece, just forward of the guard. The cartridges are placed with bullets down in two rows, and are taken out by grasping the rim by thumb and forefinger.

Data of small arms.

Name.	Nation by which adopted.	Weight of gun.	Calibre.	Weight of ammunition.			Rifling.		Muzzle velocity, feet per second.
				Powder.	Bullet.	Cartridge complete.	Number of grooves.	Twist in calibres.	
		Lbs. oz.	*Inch.*	*Gr.*	*Gr.*	*Gr.*			
Mauser, M. 71–84	Germany	10 2	.433	77	386	663	4	1 in 50	1,410
Kropatschek	French navy	9 14½	.433	81	386	676	4	1 in 50	1,430
Mannlicher, M. 85	Austria	9 8½	.433	77	371	656	4	1 in 68½	1,437
Jarmann	Sweden	10 1½	.397	77	337	620	4	1 in 55	1,536
Vitali-Vetterli M. 70–87	Italy	9 9	.414	62	312	468	4	1 in 63½	1,430
Vetterli	Switzerland	10 8	.414	55	312	465	4	1 in 63½	1,427
Remington-Lee	....	9 5¼	.45	U. S. Army cartridge.			5	1 in 50	1,301
Hebler	....	9 14½	.296	83	225	521	6	1 in 15¼	1,968
Pieri	....	....	.323	83	......	......	.....	1 in 36½	2,057
Lobell	France	....	.307	(*)	......	......	.....	....	2,034
Guédes (Kropatschek)	Portugal	....	.323	69½	264	546	(?)	1 in 35	1,673
Berdan	Russia	9 4	.42	77	370	610	6	1 in 50	1,444
Gras, M. 74–80	France	9 4	.433	81	386	676	4	1 in 50	1,430
Martini-Henry	England	8 12	.45	86	480	766½	7	1 in 49	1,253
Springfield	United States	9 1.6	.45	70	500	706	3	1 in 49	1,350
Freddi (recoil)	Proposed for Italy.	7 4	.315	83	225	398	....	....	1,640
Remington, M. 71	Spain	9 0	.433	77	386	638	6	1 in 59	1,340

* Smokeless powder.

All rifles recently adopted, except those converted, are of the smaller calibres.

Name.	Breech mechanism, nature.	Nature and location of magazine.	Cartridges in magazine.	Maximum range for which sighted.	Remarks.
				Yards.	
Mauser, M. 71–84	Bolt	Tubular, under barrel	8	1,750	
Kropatschek	....do	......do	7	1,969	
Mannlicher, M. 85	....do	Box, under breech	5	1,723	Only serviceable as magazine guns.
Jarmann	....do	Tubular, under barrel	8	(?)	
Vitali-Vetterli, M. 70–87	....do	Box, under breech	4	1,750	Adopted by Italy and styled M. 70–87.
Vetterli	....do	Tubular, under barrel	11	1,750	
Remington-Lee	....do	Box, under breech	5	1,200	Lee magazine applicable to any system of rifling.
Hebler	....do	Single-loader	....	2,843	Hebler system of rifling applicable to any magazine.
Picri	....do	Box, under breech	5	(?)	
Lobell	....do	Tubular, under barrel	8	(?)	Probably combination of Kropatschek and Hebler.
Guédes (Kropatschek)	....do	Unknown	....	(?)	Small calibre applied to Kropatschek.
Berdan	....do	Single-loader	....	1,165	Difficult to convert into magazine rifle.
Gras, M. 74–80	....do	......do	....	1,969	
Martini-Henry	Falling hinged block.	......do	....	1,300	
Springfield	Turn-over block	......do	....	1,200	
Remington, M. 71	Segmental block.	Single-loader	....	1,100	
Freddi (recoil)	Bolt	Leather box attached on the side.	12	(?)	A single loader, with a convenient method for quick firing.

Small arms adopted by various nations.

Afghanistan	Martini-Henry.
Argentine Republic	Remington.
Austria	Mannlicher, M. 85.
Belgium	Albini Braendlin.
Brazil	Comblain.
Chili	Kropatschek.
China	Remington, Snider, Hotchkiss, and others.
Denmark	Remington.
Egypt	Remington.
*England	Martini-Henry, Snider.
France	Gras, *Lobell ?* Kropatschek (Navy).
Germany	Mauser, M. 71–84.
Greece	Gras, M. 74.
Holland	Beaumont Chassepôt (modified).
Italy	Vitali-Vetterli, Vetterli, *Freddi ?*
Japan	Murata.
Madagascar	Remington, Snider.
Mexico	Lee.
Montenegro	Krinka, Dreyse.
Norway	Jarmann.
Persia	Chassepôt.
Peru	Beaumont (modified).
Portugal	Guédes (Kropatschek).
Russia	Berdan, M. 71.
Servia	Peabody-Grün.
Spain	Remington, M. 71.
Sweden	Jarmann.
Switzerland	Vetterli.
Turkey	Martini-Henry, Peabody-Martini.
Uruguay	Remington.
United States Army	Springfield.
United States Navy	Lee and Hotchkiss.
United States of Colombia	Remington.

---

* In England the committee to select a suitable magazine rifle for the English army has decided to adopt either the improved Lee or the Lee-Burton. These have detachable magazines, and the breech-bolt mechanism is the same in each gun. The Lee-Burton magazine also contains five cartridges, but on the right side of the rifle. Whenever the soldier desires to use the magazine he pulls up the case into position, so that when breech bolt is open a cartridge rolls into receiver by force of gravity through a side opening.

Hand guards of leather or canvass are also to be provided to protect the soldier's hands when the rifle gets heated by rapid firing.

VII.

MUSKETRY INSTRUCTION AT HOME AND ABROAD.

By Ensign W. L. RODGERS, U. S. N.

In considering the employment of small arms in naval warfare it is noticeable that in the United States Navy very little attention is paid either to the development of the theory of their use or of practical skill in shooting, although their importance has been demonstrated in all naval actions of late years, notably in the Russian torpedo-boat attacks on the Danube, and in the capture of the Huascar.

With regard to the theory of the employment of small-arm fire a German writer remarks as follows:

> Small-arm fire in the navy must be developed with regard to both the tactical and practical necessities and conditions of naval warfare.
>
> Modern tactics do not yet specify in detail the manner of using small-arm fire at long, medium, and short ranges against torpedo-boats or other objects moving rapidly in various directions in smooth or rough seas; or when volleys, file-firing for a limited number of rounds, or individual fire should be used.

To practice in shooting, and to fire-tactics the armies of all nations have devoted much more time and thought than their respective navies, and it will be well to commence this study upon small-arm fire by a consideration of military practice, in order that it may aid us in making such deductions and conclusions as are applicable to naval warfare, as well as because such knowledge and practice is necessary for landing forces. Such an examination is the more necessary as the actual musketry instructions of navies are based upon those of the corresponding armies.

The subject of musketry instruction may be naturally divided into two principal divisions. The first embraces the nature of the instruction and its relation to tactics; the second relates to the inducements offered to individuals and organizations to attain proficiency.

In regard to the nature of instruction in armies and its relation to tactics, there are two different systems, one of which is adopted by Great Britain and the United States and the other by the continental nations of Europe.

The principle governing the English and United States systems of instruction is that the average excellence in shooting of the individual soldier is the measure of the efficiency of the fire of the army in battle. The principle of the instruction and fire tactics of continental armies is that individuals having learned to point their rifles well, must learn to place their skill entirely under the control of their leaders, with the least possible exercise of individual judgment.

The independent fire of the United States Army is the natural accompaniment of its loose battle formation of successive lines of skirmishers without cohesion in themselves or between each other, while the necessities of fire control in continental armies require a skirmish line formed of small cohesive units supported by successive lines of closed bodies whose size increases to the rear, securing solidity by giving to each commanding officer the support necessary to carry out his own share of the action, so that command is organized in depth rather than in length.

INSTRUCTION IN RIFLE FIRING IN THE UNITED STATES ARMY.

[An abstract of Rifle and Carbine Firing, the official manual.]

The object of rifle instruction is to develop discipline and knowledge of the weapon and accuracy in its use, so as to render the fire most effective.

With this object the exercises of the individual soldier should take place at all ranges and in all weathers and on every kind of ground, and the training of the men as a body should be so conducted as to give instruction and experience in the classes of fire employed in the different stages of action, and to afford officers opportunities of acquiring practical knowledge of the best methods of conducting and directing fire.

The course of instruction admits of three main divisions:

(1) Preliminary drills and exercises.
(2) Individual range practice.
(3) Range or field practice of the company as a body.

To these should be added instruction in the estimation of distances and in the theoretical principles relating to rifle firing and to its application in action.

The target year coincides with the civil year, but in order to afford time for other drills and exercises and to permit of theoretical instruction in the principles of firing before going on the range the *practice season* or time for firing upon the range is limited to four months.

In each Department there will be an Inspector of Rifle Practice, whose duty will be, by means of reports to him and personal inspection, to keep the Department commander informed of the degree of proficiency manifested by the troops of the Department.

Post commanders are responsible for the degree and manner of instruction of their commands and will exercise supervision over all firings.

Company commanders will so conduct the instruction of non-commissioned officers that they may lend intelligent assistance in the instruction of the company.

The training of men is under the supervision of company commanders, assisted by lieutenants and non-commissioned officers.

Progress in rifle-firing on the part of the company requires that its officers should be proficient in the theoretical as well as the practical details of the subject.

With careful instruction and practice every soldier without physical defect may make his fire fairly effective at moderate ranges, say 600 yards, and a few will acquire such excellence as to extend these limits up to 1,000 or 1,200 yards.

When a company consists of men who have reached this stage of proficiency their collective fire, if properly directed, should be effective against masses of men at all ranges up to at least 1,500 yards.

After the soldier has been instructed in the nomenclature of the rifle, the precautions necessary for its care and preservation, and to some slight extent in the general principles governing the motion of projectiles, he will be thoroughly exercised in the preliminary drills. This branch of the course of instruction comprises sighting drills, position and aiming drills, gallery practice.

It is essential to hold the interest of the soldier. This can best be accomplished by limiting the length of each drill to not more than thirty minutes, and by dividing the company into squads of six or eight men each, grouping the men in the squads according to their proficiency, and shifting them from squad to squad according to their progress. The squads should be taught by the non-commissioned officers, the company officers supervising.

Sighting drills.—The instructor first explains the theory of sighting; the difference between fine and full sights is shown and the use of each is explained. He then exercises the men in pointing the rifle at small discs on the wall, so as to show them the irregularities in sighting that they commit, and to teach them to aim uniformly and to keep the sight in a vertical position.

Position and aiming drills.—The sighting drills are followed by position and aiming drills, which are intended to exercise the muscles, principally of the arms, to teach the proper methods of holding the piece, and to give the soldier, whether standing, kneeling, or lying down, a perfect command of his rifle and an unconstrained position of his body; also to teach steadiness, both of person and rifle, and to establish between the hand and eye such a prompt and intimate connection as will insure the finger's acting upon the trigger at the proper moment and without causing any derangement in the direction of the piece.

These drills should be divided into three exercises: (1) Teaching the correct position and exercising the soldier in assuming it readily; (2) adding to the first exercise the accurate direction or aiming of the piece and the retention of breathing; (3) combining with the preceding exercises the requisite steadiness of the rifle while pulling the trigger.

The manual then gives detailed directions for all these exercises in the various positions.

Gallery practice.—After the soldier has been thoroughly instructed in sighting and in position and aiming drills, he will be exercised in firing at a short range with reduced charges. As the object of the practice is simply to continue in a different manner the instruction of the preceding exercises, the firing will be held both standing, kneeling, sitting, and lying down. In order that the soldier may have experience in the appearance of the sight in its different positions and practice in the consequent changes of the position of his head when aiming, use will be made of the rear sight adjusted for the different ranges up to 600 yards.

The range should be from 50 to 100 feet, and for the 50-foot range the target should be 7 inches high by 6 inches wide, with a circular bull's eye of 1 inch in diameter, and two other circular divisions 3 and 5 inches in diameter respectively. The targets should be increased in size proportionally to the range.

An iron target 30 by 20 inches is suitable, with the bull's eye and other divisions scored in the surface. The plate should be screwed to a larger wooden screen.

The short range of 50 feet is best because the soldier can see the effect of his shot before removing his piece from the shoulder.

There must be an aiming bull's eye whose distance below the target bull's eye will depend upon the sight used and the length of the gallery range. (This is evidently necessary on account of the different trajectory and range.)

After the preliminary drills the soldier should fire a few rounds with blank cartridge before firing with ball cartridges on the range.

Range practice.—Individual range practice with service charges at targets at known ranges completes the instruction of the soldier in individual firing. It is divided into "regular practice" and "additional practice." Only the results of the former will be considered in determining the class to which the soldier belongs.

Regular practice should be held three times a week in the presence and under the supervision of a commissioned officer. The expenditure allowed for ammunition is $7.50 per annum for each man. With reloading and care this is sufficient for 1,500 rounds. Regular practice is held in scores of five shots each. Two sighting shots are allowed at ranges of 500 yards and over, but only before the first of a succession of scores.

When a soldier is called upon to fire he will inform the instructor what elevation and wind allowance he proposes to use, in order that he may form the habit of carefully making such estimations; and after firing, before the shot is signaled, he should tell at what point he aimed and where he believes his shot to have struck.

Before any practice on the range is commenced the soldier should be thoroughly practiced in the preliminary drills and be at ease in all positions for firing. Several months of this instruction will be necessary for the recruit, and at least one or two months for the soldier who in the previous year's practice exhibited only a moderate degree of proficiency.

If, however, these rudiments of the subject have been neglected, a great amount of practice will be required at the shorter ranges, 200, 100, and even 50 yards, before the soldier ascertains (if he ever does) the nature of the errors he generally commits and succeeds in eradicating them.

Each year the range practice should begin for all at the shortest ranges, and as the men qualify as second class at each range they may be advanced to a longer one, up to 500 yards. They then begin again at the short ranges, and as they qualify for the first class they are advanced to longer ranges, up to 500 yards. They then qualify as marksmen, beginning at the short ranges and advancing up to 600 yards. Marksmen should practice up to the range of 1,000 yards, endeavoring to qualify as sharpshooters.

Besides the regular firing, from which the classification and general proficiency of the soldier is determined, the soldier may be permitted as much additional practice as he may desire, or as his company commander may deem advisable.

Then follow detailed instructions for allowances of drift and elevation for shooting at each range under varying circumstances; and a great number of minute and detailed directions to riflemen for obtaining the best scores at known ranges, explaining the allowances to be made for wind, light, fouling and heating of the gun; &c.

Skirmish firing.—Towards the close of the practice season, when the men have been thoroughly instructed in individual firing at targets at known distances, they will be exercised in firing as skirmishers at figure targets at varying and undetermined distances. The practice will be divided into individual and company firing.

As the object of this firing is to afford the soldier instruction in firing at objects bearing some resemblance to those which would be presented to his aim in action, it should be conducted over broken and somewhat wooded ground, or at least over ground with which he is not familiar.

For individual practice the company will be divided into squads of from 8 to 16 men each, as may be most convenient, each squad being under the direct command of a lieutenant or sergeant. The line is deployed at 500 or 600 yards from the targets, each man having his own target. At the proper commands the line is advanced at quick time until a point a little more than 200 yards from the target is reached, when it is withdrawn in double time. During the advance 5 halts will be made and one shot fired during each halt. The same rule governs the retreat.

The individual skirmish practice will be held at least three different times; once at standing, once at kneeling, and once at lying down targets. A hit in any portion of the target, either from direct or ricochet fire, will be counted *one point.*

Company skirmish firing.—The targets will equal the number of men in the firing line; they will consist of equal numbers of standing, kneeling, and lying figures, arranged alternately with 1-yard intervals.

The skirmish line will be deployed with 1-yard intervals and the firing will be conducted as in individual skirmish-firing, except that two shots will be fired at each halt. The men need not always aim at the same figure, but will direct their fire at such points of the hostile line as they may select, or as the company commander in general terms may direct.

The officer in command and the file closers will see that the alignment and intervals are preserved during the advance and retreat; but they will be careful not to suggest to those on the firing line what they consider the distance at different times, or their estimate of the proper adjustment of the sights.

Volley firing.—If the allowance of ammunition will permit, the company commander should, if practicable, near the close of the target season, afford his command practice in volley firing. The object of this practice is not only to give the soldier instruction in a class of fire that will under some circumstances be employed in action, but also to make the company and subordinate officers familiar with this mode of controlling the fire of their commands; to accustom the men when in ranks to the habit of relying upon the judgment of their officers as to the range and approximate adjustment of their sights, the extent of their fire, and the most suitable time for its delivery.

Then follow a few remarks upon the advantages and proper employment of volley firing.

The volley firing will be against standing figures in closed line at 200 yards standing, and 500 yards and 800 yards lying down; five rounds at each range. The effectiveness of volley firing depends greatly upon the officer in command, and the regularity with which he gives his orders.

Before commencing volley practice the company should be thoroughly drilled in aiming and pulling trigger by volley and in similar practice with blank cartridges; only in this manner can the officer in command acquire a constant method of giving the commands, or the company become fully acquainted with the cadence established.

File firing.—Near the close of the target season and after the men have been thoroughly instructed in the regular range practice, they should, as far as practicable, be practiced in firing by file.

The object of the practice is to instruct the men in the rapid as well as accurate delivery of their fire, and to accustom them to the employment of a class of fire that would probably be used to a greater extent than any other in repelling the latter stages of an assault.

Practice at disappearing and moving targets.—Practice at some form of moving target should be frequently conducted, as firing at fixed targets has a tendency to make men too deliberate for field firing.

Either a disappearing or a running target may be used. When first firing at a disappearing target an interval of four seconds may be allowed, which may be reduced to three seconds and then increased to ten seconds to permit of loading and firing a second shot.

Fire at running targets should begin at 50 yards, to be afterwards increased to 100 yards. The run of the target should be 40 or 50 yards.

Targets.—The targets employed for range practice have elliptical divisions because that is the form of the shot groups when all influences except those of the arm and ammunition have been eliminated.

Three sizes of targets are used according to the range, the width and height of whose bull's eyes correspond to the mean horizontal and vertical deviations of the *carbine* for the range at which each target is used. This makes the divisions on the targets 50 per cent. larger than if they were marked for the corresponding deviations of the rifle. (See Plate 1.)

The skirmish targets are life-size silhouettes of standing, kneeling, and lying down figures. (See Plate 1.)

The construction of canvas targets and their machinery, and the preparation and building of ranges, butts, shelters, &c., is dealt with in full, but need not be discussed.

Marking and scoring.—Bull's eyes score 5 points; centres, 4; inners, 3; outers, 2; misses and ricochets, 0.

When the result of a shot is signaled it is immediately entered in the company target record on the page assigned to the soldier making the shot. This book forms the permanent record of the company.

Classification.—The firing class to which an officer or man belongs at any time will be determined by the total of the best four scores made by him during the practice season up to that date at each of certain specified ranges. The classes are six in number, namely, sharpshooter, marksman, first, second, and third classes, and "not firing" class.

The sharpshooter class is the highest, and requires to make a total score of 90 points at each of the ranges of 200, 300, and 500 yards; a total of 85 at each of ranges 600 and 800 yards, and a total of 80 at 1,000 yards.

The third class is the lowest, and is composed of those failing to score 50 at each of the 200, 300, and 500 yard ranges.

Company, regimental, and departmental classification.—The individual figure of merit for each company, regiment, or department is determined by multiplying the number of men in each class by a multiple assigned for that class, and dividing the sum by the total number of men, which gives the individual figure of merit. The general figure of merit is formed from the mean of the individual figure of merit and of the figure of merit for company skirmish firing. The latter is the percentage of the possible score obtained on the best practice.

Records.—The records are of two kinds, the company target record and the soldier's target record. The first is the official record of individual firing in the regular practice and of the skirmish, volley, and file firing of the company. It also shows the record of judging distance.

The soldier's target record is his own property, and should be so kept as to afford him the greatest help in estimating the allowances best adapted to the varying conditions of any practice. His record in individual skirmish practice should also appear in it, as well as his estimates at distance drill, which will help him to correct future estimates.

Reports.—Monthly and annual company reports of target practice are rendered, in the latter of which the figure of merit is computed for the company in such a way that a large figure of merit requires full numbers in the ranks as well as good shooting. Regimental and departmental annual reports of target firing are also made out.

Rewards.—Badges are awarded to sharpshooters and marksmen. The sharpshooter's badge is worn permanently, and a bar is added to the badge for each three years during which qualification is renewed. The marksman's badge may be worn only until the close of the target year next succeeding the year of issue, unless qualification is renewed. A marksman's pin, which is issued for three qualifications as marksman, is worn permanently. Certificates of qualification are also issued to each marksman and sharpshooter.

Competitive firing.—To further increase the interest of the Army in good shooting annual competitive firings are instituted, for success in which rewards are offered.

The necessity for regular life, perfect discipline and training in the team is pointed out, so that the members may aid each other and act as a unit.

The competitive firing in the Army takes place annually in department teams. The team is selected from the best shots among the officers of each regiment and the men of each company, who compete together for places on the team.

The firing is at fixed targets at known distances, with skirmish fire at undetermined distances. The composition of the team is determined by the aggregate scores for both classes of firing. The skirmish firing is both for rapidity and accuracy, the number of cartridges carried being unlimited, but only fifteen seconds for firing is allowed at each halt. The twelve men with the best records form the department team and the next two are alternates.

A gold medal is given for the best total record, and a silver medal for the best skirmish firing, these medals becoming the absolute property of the winners.

Divisional matches take place between the department teams firing as individuals. Four gold and eight silver medals are awarded for the best total records, besides a silver medal for the best skirmish firing.

The Army competition takes place every alternate year between twelve of the best shots of the Army, selected as designated in general orders, and competing as in department matches. The prizes are three gold and three silver medals for best total records, and one gold medal for best skirmish record.

Then follow regulations for conducting matches, also a discussion of the ballistic qualities of the rifle and the trajectory of the bullets as affected by temperature, elevation above the sea, wind, moisture, variations in the ammunition and rifle, &c., showing the effect in causing variations in individual shooting and single shots.

Effects of fire.—Then follows a definition of the dangerous space, showing its importance when the shooting is not very accurate and the range uncertain and a discussion upon the influence of the slope of the ground on the effect of fire.

Employment of fire in action.—The different kinds of fire most appropriate for the various stages of an action depend upon the size of the object, especially as compared with the height of the shot group, and upon the greater or less certainty of the range, the degree of the soldier's proficiency with his weapon, the moral condition of the troops, the amount of ammunition, and, finally, upon the accuracy of the rifle and the flatness of the trajectory at different ranges.

As a general rule, the fire of the average individual soldier will not prove effective without the expenditure of considerable ammunition when directed upon a single man lying down at a distance greater than 250 yards, or upon one standing beyond 500 yards. At 900 yards the fire would be effective against a line of skirmishers with one yard intervals, and it would be effective against small compact bodies of artillery or cavalry up to 1,500 or 1,800 yards.

For troops behind shelter acting on the defensive, the employment of volley firing possesses many advantages. It enables the officers to govern the direction of fire and control its extent and the expenditure of ammunition. It permits the officer to regulate the adjustment of the rifle sights and require all to adopt the one deemed most appropriate; and finally it affords the officer the best means of retaining a full control over his men; an element of great importance, especially in the case of undisciplined men.

For the offensive, volley firing should be conducted by troops especially selected and posted on the flanks of the attacking force, or upon some dominant position in the rear. The element of immobility and relative security incident to volley firing is entirely incompatible with a vigorous offensive and makes its employment by troops executing the attack unadvisable. Individual or independent fire conducted slowly at first, or with frequent pauses, is preferable; the pauses permit the smoke to clear away and the officers may observe the effects of fire, make such changes as may be advisable in the disposition of troops, and re-establish calmness and steadiness among the men.

Estimation of distances.—The men are first taught to measure distances by pacing, and then to estimate them by sight and by sound under varying circumstances.

REMARKS.—The course of instruction given to the United States army may be summarized as follows:

Careful and thorough instruction in preliminary exercises and pointing;

Thorough practice at known ranges, the ranges increasing with the skill of the men;

A little practice in volley and file firing at the discretion of the company commander;

A very litle practice in uncontrolled skirmish firing;

Instruction in estimating distances.

The criticism which may be made on this course of musketry instruction is that, although the importance of collective firing is strongly urged, as yet little effort has been made to develop skill in it by practice.

The tables given of dangerous spaces for different ranges are peculiar, for they differ for the standing and lying down positions. This arises from the assumption that aim is taken at a fixed point at a given range, and the object to be hit moves past the point of aim. Were aim taken at a given point of the moving target, the dangerous spaces would be independent of the position of the marksman; this is evidently what would occur in practice, and tables are usually made out on this supposition.

MUSKETRY INSTRUCTION IN THE BRITISH ARMY.

[From Regulations for Musketry Instructions.]

The musketry instruction of the British army has been much behind that of continental armies, but in the "Regulations for Musketry Instruction, 1884," considerable advance has been made towards the continental methods. There is nothing important to be learned from their detailed examination, as they resemble those of the U. S. army.

REWARDS.—The system of annual rewards for marksmanship and skill in judging distance differs from that of the U. S. army.

Gold embroidered badges worn on the sleeve and prizes of from £5 to £2 are given to the best and second best shots of regiments and best shots of companies. In addition to these winners, those qualifying as "marksmen," to the number of 10 per cent. of each company, wear a worsted badge and receive £1. If more than 10 per cent. of a company qualify as "marksmen" those in excess wear the badge only. No man takes more than one prize, but the full allowance of prizes is issued for each company, *i. e.*, a man winning the regimental prize cannot take his company prize, which is issued to the next best man in the company.

A prize of £1 is given to the best judge of distance in each company, and a prize of 10*s*. to 10 per cent. of the company if they qualify.

The qualification requires 24 points out of a possible 48. Points are given thus: When the correct distance is not over 500 yards, within 20 yards scores 2 points, and within 30 yards 1. At distances greater than 500 yards, within 30 yards scores 2 points, and within 40 yards scores 1.

FRENCH ARMY MUSKETRY INSTRUCTION.

[A summary of the instruction prescribed in *Règlement sur l'Instruction du Tir* of 1882.]

In each regiment the musketry instruction is under the direction of the colonel. The lieutenant-colonel regulates all the details of instruction. A captain is designated as range officer of the regiment, and a subaltern from each battalion as range officer.

The regimental musketry school gives theoretical and practical instruction and range practice.

The lieutenant-colonel occasionally assembles all the officers and examines with them those parts of the instructions which are capable of development.

Battalion commanders explain to their officers all the parts of the present regulations, and, besides, exercise them in judging distances and in the regulation of fire. Each year before beginning instruction the range captain causes all subaltern officers to execute the complete series of preparatory exercises. The range officers of each battalion are responsible under the range captain for the theoretical and practical instruction of non-commissioned officers.

To fire a gun at a target three distinct actions must be united in a single operation, namely: To point the weapon, first preparatory exercise; to keep it pointed, second exercise; to pull the trigger, third exercise. The pupil is then taught to unite all the operations, fourth exercise.

In the first exercise the rifle is placed on a gun-rest and the pupil is taught to catch the line of sight, to direct it on an object; then to use the sights for different elevations and to test the regularity of aiming. He is then shown the corrections to be made in aiming, and a demonstration is made of the function of the rear sight.

The French rifle has a leaf sight, with four fixed sight notches on the leaf for 200, 300, 350, and 400 metres; beyond 400 metres the leaf is graduated for each 25 metres up to 1,800 metres.

The rules for using the sight are as follows: For ranges of 200 metres or less use the 200-metre sight; between the 200 and 300 metres use the 300-metre sight; between 300 and 350 metres use the 350-metre sight; between 350 and 400 metres use the 400-metre sight. Beyond 400 metres set the sliding leaf to the range.

In the second exercise the arm is placed in the hands of the soldier, and he is taught the standing firing position, and how to look over the different sights when himself holding the piece; to hold his breath, and, finally, to sight the gun at a given point using diffferent elevations. The same instruction is then given in the kneeling and lying positions.

In the third exercise the pupil is taught to pull the trigger.

In the fourth exercise the pupil is taught to pull trigger at will, without deranging the pointing with each of the lines of sight, and in each of the standing, kneeling, and lying positions.

The pupil then is exercised in pulling trigger at the command of the instructor.

The instructor next exercises a squad in firing squad-volleys at command, taking care to designate a point of sight sufficiently distant for the pieces to be sensibly parallel.

As skill in firing is only obtained by constant practice, reduced charges are used in order to exercise the men without too great expense.

The allowance of reduced charges is 100 per annum for each man.

This practice is both at will and by command, individually and in squads, and in each of the standing, kneeling, and lying positions.

A register of target practice with reduced charges is kept as for regular practice.

Estimating distances.—Two methods of judging distances are taught—by sound and by sight.

Before teaching the men to estimate distances they are taught to measure them.

The men are exercised to pace uniformly, and to remember how many paces they make in 10 metres and in 100 metres, and these numbers are used as units.

The estimation of distances by sight is taught in substantially the same manner as in the U. S. Army.

The estimation of distances by sound is based upon the interval between the flash of a gun and its report, allowing 3 seconds for 1,000 metres. It is susceptible of great accuracy. The men are taught to count ten in three seconds, and when the cadence is thoroughly impressed, a squad is sent off to a distance and fires a volley of blank charges; the main body estimates the distances by counting off the interval. In a well-instructed company the mean error at 1,000 metres should be less than 50 metres.

Target practice.—Target practice includes individual practice, collective practice, battle practice, special practice, and revolver practice; the latter will not be considered here. The annual allowance for practice is 120 rounds of ball cartridge and 50 rounds of blank cartridge.

Individual practice is divided into instruction practice and applied practice.

Instruction practice has a double object: (1) To teach the soldier the value of his weapon and to utilize its precision within the limits of individual fire; (2) to ascertain the degree of skill developed by the marksman.

The allowance for instruction practice is 75 rounds of ball cartridge and 7 rounds of blank cartridge, and is expended at ranges from 100 to

600 metres in each of the three regulation positions. Of this allowance, 3 rounds of blank and 3 of ball cartridge are fired by command at 400 metres.

The targets are shown on Plate 1. At 100, 200, and 300 metres two points are scored for each shot in the inner circle, one point for each shot in the outer ring, and zero for all other shots on the target. At 400, 500, and 600 metres two points are scored for all shots upon the surface to be hit, and zero for all shots outside that surface.

In applied practice it is the object to teach the soldier to fire from any position upon special targets presenting to the eye an appearance resembling that of objects met with in war. The targets are black paper silhouettes, representing men standing or kneeling, in their true size. This practice should, if possible, be carried out on other than the usual practice ranges, and at ranges not corresponding to the graduation of the sights. The allowance for this practice is 18 rounds at from 175 to 525 metres. Each shot on the target scores two points, ricochets scoring the same as direct hits.

Collective practice.—When the soldiers are familiarized with individual fire they are taught to fire together. Collective firing is divided into volley firing and file firing.

Volley practice exercises the officers in regulating the fire in range and direction. It accustoms the non-commissioned officers to the exercise of command, gives to the men the necessary coolness, and accustoms them to remain under the control of their officers. It takes place at 600, 800, and 1,000 metres; expending 3 blank rounds at each range, 3 rounds of ball cartridge at 600 metres and 6 rounds of ball cartridge at the other ranges. The squads must have not less than 6 men at 600 metres, 12 men at 800 metres, and 24 men at 1,000 metres.

The object of file firing is the exercise of the men in the application of the rules of fire at unknown ranges. Twelve rounds are expended in file firing in two exercises. In the first exercise the range is between 150 and 300 metres, but the 300-metre sight, which is the real sight for close action, must be employed, and aim taken at the foot of the target. In the second exercise the range is from 400 to 600 metres, and the line advances by rushes of about 50 metres, firing two rounds at each halt with the sights ordered by the chiefs of section. The section must number at least 24 men. The targets in file firing are silhouettes.

These exercises consume the allowance of 120 rounds of ball cartridge.

A company record is kept of the result of the collective firing.

Battle practice.—The allowance for battle practice is extra and is made upon special requisitions.

Battle practice has for its object the instruction of all ranks in fire conduct and fire discipline. Soldiers will find in it occasions for applying the principles which have been taught them in regard to the utilization of accidents of the ground and the judicious employment of their weapons.

This practice calls for a large irregular ground, permitting fire without danger in all directions, and also variations in the arrangement and appearance of objectives and the development of likely tactical themes; and its proper execution demands constant exercise in the regulation of fire.

Battle practice must represent certain instants of an offensive or defensive action; it accustoms officers to combine the rapid execution of movements demanded by an unforeseen situation with the judicious employment of different kinds of fire under the varying circumstances of ground and the assumed tactical conditions. It must not therefore be attempted to regulate a battle practice, nor to cause it to follow a definite development; on the contrary, all idea of experiments relative to the value of different kinds of fire and of the vulnerability of formations should be proscribed. The exercise should be confined to the execution of very simple themes, representing one or more phases of an action.

Battle practice should be an imitation of battle. It should include a variable number of meetings (*séances*), and be divided into two exercises:

(1) Company engagement.

(2) Battalion engagement.

The firing will take place at unknown ranges according to tactical themes, the screens being placed at the points which in a real action would be occupied by the enemy.

The precise instant for beginning the execution of the theme selected is indicated by the superior officer directing the manœuvre, who makes known the time during which the target is supposed to be visible, or the time granted to the commandant of the troops for the execution of the programme assigned to him.

His explanations given, the director of the exercise indicates the commencement of the preparatory manœuvre by the bugle calls, "Attention," "Advance," and the end of the exercise by the calls, "Halt," "Cease firing."

For the execution of battle practice companies are formed with effectives of about 200 men and war staffs of officers and non-commisioned officers.

The second exercise, which must be carried out whenever the force and ground will permit, is executed regimentally, each regiment forming one or two battalions at war strength, 200 to 250 men per company. The officers and non-commissioned officers not engaged attend the exercise and the critique which takes place thereafter.

The front and density of the targets must be in proportion to the demands of the hypothesis on which the exercise is based.

When the firing is completed, the results are scored off, and the superior officer in charge makes on the spot a critique of the manœuvre before all the assembled officers, in which, having regard to the assumed hypothesis, he comments upon the manner in which the preparatory manœuvre was directed, the dispositions taken, the choice of positions, the sights used, the kind of fire employed, and the general conduct of the action.

Special practice.—This practice is executed only by first-class marksmen, always in the kneeling position. It includes firing 12 shots at a disappearing or running target at 200 and 300 metres, and firing a string of 10 rounds at a fixed target at 200 metres; a plan of his string is given to the soldier as his personal record. It is to be regarded as an honor and reward for first-class men.

Classification and rewards.—After the individual practice for the year is finished the annual classification of marksmen is carried out. The preparatory firing (12 rounds) and firing by command (3 rounds) do not count for classification. This leaves 78 rounds which count for classification, of which 18 are at figure targets. Those having at least 64 points form the first class; those having at least 36 points, the second class; and those having less than 36 points, the third class.

Rewards are of two kinds: (1) those given on the general result of firing, counting for classification; (2) those given after matches. Both kinds are honorary rewards intended to indicate good marksmen to their chiefs and comrades.

The rewards for the general record of the year consist of a gilt silver hunting horn, with pin and chain, for the best shot of the regiment, and thirty-six embroidered hunting horns per regiment for the best shots (this is about three badges per hundred men). The pin becomes the property of the winner, but to wear the embroidered horn a second year the man must renew qualification.

A second class of reward, in the shape of a scarlet-cloth hunting horn, is worn for the year on the sleeve by all first-class men. The names of winners of rewards are published in regimental orders, posted in company quarters, and entered in the personal record books.

The annual regimental match takes place between the eight best marksmen (corporals and soldiers) from each company of the regiment, and all winners of annual prizes in one division and all non-commissioned officers having a record of first class in another division. Each man fires 6 rounds at 200 metres at the target shown (Plate 1), scoring 1, 2, or 3, as shown. A gilt silver hunting horn, with pin and chain, is given to the winner in each division, and nine silver horns to the next best records among the corporals and privates, and two silver horns to the next best records among the non-commissioned officers.

In comparing the course of instruction just described with that of the United States Army, it will be noticed that the methods of teaching the soldier to point his weapon are very similar, but that when this has been accomplished it is the aim of the French instruction to cause men to fire according to the wishes of their officers (collective practice) and to accustom them to fire as they would in battle (battle practice), and this instruction has scarcely any counterpart in that of the United States Army.

It appears, however, from an article on target practice in Farrow's Military Cyclopedia, by the author of "Rifle and Carbine Firing," which is the United States Army official text-book, that it is his hope that the standard of instruction in the United States Army may be gradually advanced towards that of continental nations.

THEORETICAL INSTRUCTION.—The second part of the French manual consists of theoretical instruction regarding firing, some points of which it will be well to examine.

The preliminary remarks upon the shape of trajectory and the resistance of the air may be passed over as already familiar to officers.

The flatness of trajectory is one of the principal qualities of a military rifle because upon it depends the extent of the dangerous zone and the efficacy of ricochets.

Shots directed at the same point with the same sight strike the target at different points, as each bullet has a vertical and horizontal error with regard to the point aimed at.

If a shot-group formed by a large number of bullets is considered, the different trajectories described by the bullets form a sort of sheaf or curved cone, which leaves the muzzle and goes on widening as the distance of the marksman from the target increases. The ideal curve placed at the centre of the sheaf and forming, so to speak, its axis, is called the mean trajectory. (See Fig. 8, Plate 2.) Experience shows that the points of impact of a large number of bullets are spread over a space which is larger as the target is farther off. Sections made perpendicularly to the axis of the sheaf approach the general form of ellipses whose axes increase as they are farther from the marksman. Shooting is better as the sections at a given distance from the marksman are smaller.

When a number of men fire at the same object with the same sight, we must add to the causes of dispersion and deviation in the fire of single men those which arise from the multiplicity of marksmen and of weapons. The result is a series of trajectories which together form a sheaf similar to those of individuals, but having dimensions larger in every direction. This is shown in the following table:

TABLE A.—*Showing the accuracy of fire of the French infantry rifle, model of 1874.*

Ranges.	Shot-groups on a vertical target.								Shot groups on a horizontal target.			
	Height of the horizontal zone of indefinite length, whose axis passes through the center of impact, and which catches 50 per cent. of the bullets fired.				Width of the vertical zone of indefinite height, whose axis passes through the center of impact, and which catches 50 per cent. of the bullets fired.				Depth of the zone perpendicular to the direction of fire, and of indefinite length, whose axis passes through the center of impact, and which catches 50 per cent. of the bullets fired.			
	Individual firing.		Collective firing.		Individual firing.		Collective firing.		Individual firing.		Collective firing.	
	Very good.	Average.	Very good.	Average.	Very good.	Average.	Very good.	Average.	Very good.	Average.	Very good.	Average.
Metres.	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Cm.*	*Metres.*	*Metres.*	*Metres.*	*Metres.*
100	9.0	18.4	24	46	7.6	16.0	19	38	27	54	71	136
200	20.0	37.8	50	100	16.0	32.4	40	80	26	51	65	130
300	32.2	57.4	80	162	25.2	49.0	64	126	25	44	61	123
400	45.8	78.8	114	230	35.4	66.2	88	176	23	40	58	117
500	61.0	100.6	152	306	46.4	84.0	116	232	22	36	56	111
600	78.0	125.4	196	390	58.4	102.4	146	292	21	34	53	107
700	97.0	148.0	242	486	71.8	121.4	180	358	21	32	51	102
800	118.2	174.4	296	592	86.6	141.6	216	432	20	30	50	99
900	141.8	202.0	354	710	102.0	163.0	258	516	19	28	48	96
1,000	168.0	232.0	420	840	122.0	186.0	306	610	19	26	47	94
1,100	197.0	264.0	492	986	145.0	211.0	360	720	18	25	46	92
1,200	229.0	299.0	572	1,146	169.0	239.0	424	846	18	24	45	90
1,300	266.0	338.0	666	1,330	199.0	270.0	498	996	18	23	44	89
1,400	308.0	381.0	770	1,540	235.0	306.0	586	1,172	18	22	44	88
1,500	356.0	429.0	890	1,780	276.0	347.0	692	1,382	18	22	44	88
1,600	410.0	483.0	1,026	2,040	326.0	396.0	816	1,632	18	22	44	88
1,700	472.0	545.0	1,180	2,360	386.0	453.0	964	1,930	18	22	44	88
1,800	544.0	616.0	1,360	2,720	456.0	521.0	1,142	2,282	18	22	44	88

NOTE.—It is worthy of notice in this table that the relative superiority of good over average individual marksmanship decreases very much as the ranges increase: when it is considered that the dificulty of directing and controlling individual fire increases enormously in battle while with collective fire it increases less; and that skill in collective fire is a matter of practice, rather than of natural aptitude, and that it maintains its superiority at all ranges; it seems apparent that the time spent informing long range sharpshooters might be much better spent in collective firing.

The groupings thus formed by the shot either on a vertical screen, or on the ground are called collective groups. It is often difficult to catch these shot-groups on a vertical screen, especially at the greater ranges, and when the number of marksmen is large; it is therefore convenient to study them on the ground to see how the shot are distributed.

A fairly exact idea of the grouping is reached in considering the width and depth of the beaten ground, including either all, or the best half of the shots. The beaten ground is that upon which the bullets fall.

The group formed either on a vertical screen or on the ground takes the shape of an ellipse with its long axis in the plane of fire.

When the ground is horizontal or parallel to the line of sight, the depth of ground beaten by direct striking bullets, fired with the same sight at the same object, is sensibly constant at all ranges. It averages about 300 metres if we consider 90 per cent. of the shot, disregarding the longest and shortest ones, and it is about 100 metres if we disregard 50 per cent. and take only the densest part of the group. (See Fig. 1, Plate 2.) These figures are not absolute, and may evidently be greater or less according to the skill of the company; but the dispersion in depth is nevertheless independent of the range, although it varies with the inclination of the ground, as will be shown further on.

The width of the beaten ground, on the contrary, increases with the range; it is about 5 metres at 500 metres, 10 metres at 1,000 metres, 15 metres at 1,500 metres for 90 per cent. of the shot; but this proportion does not hold good beyond 1,500 metres, for at 1,800 and 2,400 metres the widths of the beaten ground are respectively 20 and 40 metres.

The surface of that part of the group containing the best 50 per cent. of shot is called the nucleus, the ring containing the next best 40 per cent. is the envelope, and the rest is called the tailing.

The centre of the nucleus is the mean point of impact of the horizontal grouping, and around it the shot are the thickest. As, in individual fire, it is necessary to cause the mean point of impact to fall upon the target, so in collective firing it is essential to cause the densest part of the nucleus to fall on the target.

According to the nature, form, and particulars of the ground, and the arrangement of the target on the ground, the effects of fire vary in the angle of graze, the ricochet, and penetration. It is very important to study these different effects and the way in which they are increased or diminished. Such knowledge will permit a rational employment of fire, and a choice of position least favorable to the enemy.

A fire is said to be more or less grazing with respect to a given ground in proportion as the projectiles travel a greater or less distance at a small height above the ground, rendering dangerous a greater or less space.

It is on the angle of graze that the vulnerability of formations partially depends as well as the protective value of accidents of the ground.

The effects of the graze vary with the flatness of the trajectory, the range, and the conformation of the ground. When the profile of the ground is parallel to the line of sight, the effects of the angle of graze and of the fire in general are the same as if the ground were level and at the same height as the origin of fire.

It is therefore necessary first to examine the effects of graze on horizontal ground, which depend especially upon the extent of the dangerous zone.

Dangerous zone of a single trajectory.—The dangerous zone for a target of given height and for a given trajectory is the depth of ground on which the target cannot be placed without being struck. The height of the trajectory at any point of the dangerous zone is therefore less than the height of the target. (See Fig. 6, Plate 2.) Thus, for a height of target C D, the dangerous zone of the trajectory T A D extends from B to D. The factors upon which depend the extent of a dangerous zone are the flatness of trajectory, the range, the height of the target, and the configuration of the ground at which the fire is aimed. Suppose two pieces at the point O, fired with sights adjusted for the range O A. (Fig. 7, Plate 2.) Let A M be the height of target; O B A and O C A, the two trajectories meeting at A, the foot of the target. The dangerous zone A P, corresponding to the trajectory O B A, will be greater than the dangerous zone A R, corresponding to the trajectory O C A, which is not so flat as the former.

The dangerous zone on horizontal ground, or ground parallel to the line of sight, diminishes as the range increases. Thus the dangerous zones for an upright man (height 1.60 metres) at 500, 1,000, and 1,500 metres are, respectively, 71 metres, 18.5 metres, and 8.2 metres, with the gun of 1874 model.

Besides, the dangerous zones increase or diminish with the height of the target. Thus for a kneeling man (height 1.0 metre) the dangerous zones at the above mentioned ranges are, respectively, only 41 metres, 11.5 metres, and 5.1 metres.

At long ranges, on account of the increase in the angle of fall, the dangerous zones are practically proportional to the height of target. When the greatest height of the trajectory is not greater than that of the target, all the space between the muzzle and the striking point is the dangerous zone.

TABLE B.—*Dangerous zones of the French infantry rifle, model of 1874, taking the foot of the target as the point of sight.*

Range.	Dangerous spaces, for—			
	A rider, height 2.5 metres.	A standing man, height 1.6 metres.	A kneeling man, height 1 metre.	A lying man, height 0.5 metre.
Metres.	*Metres.*	*Metres.*	*Metres.*	*Metres.*
100	100	100	100	100
200	200	200	200	200
300	300	300	300	46.0
400	400	131	62.5	28.2
500	134	71	41.0	19.5
600	82.8	54.2	28.6	14.3
700	59.6	39.2	22.1	11.0
800	45.4	28.2	17.4	8.7
900	36.1	22.6	14.2	7.1
1,000	29.1	18.5	11.5	5.7
1,100	24.0	15.4	9.6	4.8
1,200	20.2	12.9	8.1	4.0
1,300	17.2	11.0	6.9	3.4
1,400	14.7	9.4	5.9	2.9
1,500	12.8	8.2	5.1	2.5
1,600	11.1	7.0	4.4	2.3
1,700	9.9	6.3	4.0	2.0
1,800	8.6	5.5	3.4	1.7

NOTE.—In this table no allowance is made for the height of the muzzle of the rifle, as the dangerous space is measured parallel to the line of sight. This seems a better method of calculating the dangerous spaces than that employed in the United States Army Manual.

An examination of table B shows that for a man lying down (height 0.5 metre) the dangerous zone corresponding to the 200-metre trajectory is 200 metres. That is to say, the height of this trajectory above the ground is always less than that of a man lying down, so that with the 200-metre sight all the space from the origin to the striking point of the trajectory is dangerous for a man lying down.

Similarly the 300-metre trajectory, whose height is 0.90 metre, is dangerous throughout for a kneeling man; that of 350 metres (height 1.30 metres) is dangerous throughout for a standing man, and that of 400 metres (height 1.75 metres) is dangerous throughout for a rider, supposing that the fire is executed under normal conditions, and that the foot of the target is the point of sight.

The 300-*metre sight is therefore the real fighting sight for short ranges.*

The employment of fixed sights, however, renders it necessary to consider the height of the enemy and his distance.

For instance, to strike a man lying down at a distance of 225 metres, using the 300-metre sight, aim must be taken below the man, because the ordinate at 225 metres of the 300-metre trajectory is more than 0.5 metre.

Influence of the ground on the extent of dangerous zones.—Suppose the ground instead of being parallel to the line of sight to be inclined to it. It is easy to see that on ground rising, as at D or F (see Fig. 2, Plate 2), above the line of sight the extent of the dangerous zone is diminished, because the angle of the trajectory with the ground is increased.

The contrary is the case on the ground B or P.

But the increase in the dangerous space in the latter cases is not indefinite, for when the inclination of the ground is greater than that of A P, parallel to the tangent M N to the trajectory at the point M, the middle part of the descending branch will pass over a target whose height is A M. It is evident that if the slope of the ground is about parallel to the angle of fall of the projectile the dangerous space will be great.

Defiladed zones.—A defiladed zone for a given obstacle and a given range is the ground which the obstacle shelters from projectiles fired at that range.

This zone is the space C A (see Fig. 3, Plate 2), extending from the foot of the obstacle to the striking point of a trajectory, grazing the top of the obstacle. A man behind this obstacle is completely exposed if he is beyond the defiladed zone. He begins to be sheltered at the point A, where the zone begins, but will be completely sheltered only after advancing over the dangerous zone A B, which depends upon the trajectory grazing the crest. The defiladed zone C A must be diminished by the dangerous zone B A to find the extent B C of absolute protection afforded to a target whose height is A H.

If the height of the obstacle is less than that of a man he cannot get complete shelter, but any shelter is valuable. Defiladed and protected zones vary in depth precisely as do dangerous zones, increasing with the height of the obstacle and inversely as the range, and they are affected by the slope of the ground behind them.

Influence of the slope of the ground upon the beaten zone of collective firing.—Let us consider a sheaf of trajectories leaving the point O. (Fig. 9, Plate 2), the line of sight being directed at the point A, behind which the ground has different inclinations. If the nucleus of the sheaf is limited by the trajectories O N, O N′, the surface struck on a vertical target, A V, will be represented by A V′. Now, as the ground slopes and takes the positions A C, A D, A H, A P, the depth of the beaten zones becomes greater and passes successively through the values A C′, A D′, A H′, A P′. Finally it reaches his greatest extent A F′ on the surface A F, tangent to the trajectory O I A, passing through A and representing the mean trajectory of the sheaf.

Beyond this inclination begins a series of grazing fires to the slope. A R is reached, where the height of the trajectory passing A is not greater than 1.60 metres. Beyond A, in this case, there will be a space not beaten by the bullets, but dangerous throughout, because the height of the trajectory is not more than 1.60 metres (a man's height). The front part of the nucleus has on the ground O A in front of A its own beaten zone and grazed or dangerous zone. These spaces depend on the angle between the slope and the line of sight, and are independent of the angle between the latter and the horizon.

It follows from these considerations that the extent of the beaten zone alone is not a complete measure of the efficacy of the fire, but the dangerous zone is composed of the beaten ground and the grazed zone, as shown by Figs. 5 and 9, Plate 2.

(Fig. 5.) Ka, grazed zone;—a A D′, beaten ground;—k a A D′, dangerous zone.

(Fig. 9.) Case of the ground O A R. K a, grazed zone;—a A, beaten ground;—A R′, grazed zone;—R R′, beaten ground;—K a A R′ R, dangerous zone.

(Fig. 9.) Case of ground O A F. K a, grazed zone;—a A F′, beaten ground;—K a A F′, dangerous zone.

The depth of the grazed zone is nothing more than the dangerous zone of the lowest trajectory. If in the interior of the sheaf of trajectories forming the beaten ground each trajectory is separately considered, it will be noticed that each one has its own dangerous zone, and that the chances of striking an object placed on the beaten ground will be greater as these individual dangerous zones are greater, or, in other words, as the beaten ground is better grazed.

If the grouping of the sheaf with regard to a plane parallel to the line of sight, or a horizontal plane is considered, it is seen that the grouping is shortened on ground inclined above the line of sight and lengthened on ground sloping below the line of sight.

In a collective fire at a range of 1,000 metres, the nucleus containing the best half of the shots will be 8.54 metres high, its depth on level ground will be 100 metres, extending from the 950-metre to the 1050-metre range, and the nucleus will be included between the two trajectories corresponding to these ranges. If the trace of these two extreme trajectories is sought on grounds of different slopes, the following results are obtained:

Amount of slope.*	Depth of beaten ground with 1,000-metre sight.	
	Ground sloping above the line of sight. (See Figs. 1, 2, 3, and 4, Plate 3.)	
$\frac{1}{10}$=10 per cent.	50 metres—from 975 to 1,025 metres.	
$\frac{1}{20}$= 5 per cent.	65 metres—from 968 to 1,033 metres.	
$\frac{1}{50}$= 2 per cent.	82 metres—from 960 to 1,042 metres.	
	Ground sloping below the line of sight. (See Figs 5 and 6, Plate 3.)	
$\frac{1}{10}$=10 per cent.	365 metres, or 247 metres.	According as the whole nucleus or only half of it is caught on the sloping ground.
$\frac{1}{20}$= 5 per cent.	184 metres, or 96 metres.	
$\frac{1}{50}$= 2 per cent.	124 metres, or 62 metres.	

For slopes of less than $\frac{1}{50}$ above or below the line of sight, the depth of ground beaten by the 1,000-metre sheaf tends to approach 100 metres, which is the depth of the nucleus on ground parallel to the line of sight.

But on these grounds of little slope the groupings formed by the short-range sheafs vary more with a change of slope than those of long ranges on greater slopes, with the same change of slope.

When it is noticed that alteration of the form of the shot group on the ground according to the inclination of the latter is independent of the form of the sheaf, it is easy to see that a vertical target placed within the sheaf will always be struck in the same manner without regard to the slope of the ground on which it is situated, so that the result of firing at a shallow target, a line formation for instance, is independent of the slope of the ground.

But the case is not the same for deep formations or successive lines. Thus, for a second line to be sheltered from fire directed at the first, it must be so far behind the latter as to be out of the shot group, and this distance is greater as the trajectories are more grazing.

A company in battle formation, therefore, will not have the same relative security on all grounds. If the total depth of the company battle formation is 500 metres, all the lines may be within the same sheaf on ground sloping below the line of sight, while on ground sufficiently inclined above the line of sight the other lines will be sheltered from fire directed at the first. (See Fig. 4, Plate 2.)

On the other hand, deep closed formations, such as a company column, have the vulnerability of a vertical target whose height is greater as the range and angle of fall of the bullets increase.

Thus at 800 metres the column would be represented by a target 2.44 metres high; and at 1,700 metres, by a target 5.41 metres high. (See

---

* The above slopes express the inclination of the ground to the line of sight, cutting the mean trajectory at 1,000 metres.

Fig. 10, Plate 2.) It thus has considerable vulnerability, which also varies as the slope of the ground alters the virtual height of the column by raising or lowering the rear files. This formation will suffer less loss on ground sloping below the line of sight than on horizontal ground, and this case will be particularly marked when the ground is so much inclined that the trajectory grazing the crest leaves a sort of defiladed zone in rear. On ground sloping above the line of sight the circumstances are quite different, for the formation would catch some trajectories which would pass over it on level ground.

In general, on ground sloping above the line of sight, the fire is less grazing and the shot groups denser, the targets are more visible and the ricochets higher. The observation and connection of fire is easier than on level ground.

On ground sloping below the line of sight the graze is longer, but it is difficult to observe effects. The effect would depend on chance if invisible targets were aimed at, but fire grazing ground sloping below the line of sight will often be useful when a target is visible within easy range at the front edge of the hidden ground, because behind the visible line there must be reserves which, in advancing, must pass through a dangerous ground of great depth.

It is important to know the effects of grazing fire on inclined ground, especially to guard one's self against it, but if fire is properly used accuracy must not be sacrificed in seeking to profit by this class of fire on supposed objectives. On rolling ground, however, fire may be kept up even when the advancing enemy is momentarily invisible.

Ricochet firing.—When fire is aimed upon a level and firm ground bullets ricochet up to a range of 1,700 or 1,800 metres, and the length of the ricochet is 300 or 400 metres at short ranges, 200 to 300 metres at mid ranges, and 100 to 200 metres at long ranges.

Besides, ricochets spread laterally, covering a wider space than do direct hits, with a tendency to carry towards the left with rifling from right to left. The width of ground beaten by ricochets is from 30 to 40 metres, and seems independent of the range. It follows that a target may be struck by shots falling short which ricochet.

The circumstances which seem to give the best results are when the densest part of the sheaf falls at the foot of the target, supposing the latter to be of little depth. Hard ground is most favorable to ricochets. Hollow ground is more favorable to ricochets than convex ground. (See Figs. 11 and 12, Plate 2.) The dust raised by ricochets is favorable to the observation and adjustment of fire.

Indirect fire.—Under the head of indirect fire the manual shows the solution of the problem of striking an invisible object by aiming at a visible bench-mark in front of the target. It requires full data regarding the relative height above the sea of marksman, target, and bench-mark as well as the ranges, when the tables given in the manual afford the solution, but the problem is applied only in sieges, &c.

Limits for opening fire.—The limits for opening fire depend on the accuracy of weapons, knowledge of the range, the size of the target, the skill of the men, and the nature of the ground.

In war, account must be taken of the moral state of the men and the available ammunition supply. Absolute limits for employment of fire, therefore, may not be laid down.

Still, experience shows that the following are the ranges beyond which expenditure of ammunition is usually excessive with regard to the results obtained:

At 200 metres against a man lying down or sheltered
At 300 metres against a standing or kneeling man.
At 450 metres against a single rider.
At 500 metres against a single squad lying down.

Fire may be opened against skirmish lines as follows:

At 500 metres on a thin line (5 metres interval).
At 600 metres on an average line (2.5 metres interval).
At 800 metres on a thick line, or on a company in open order, whatever may be the density of its skirmish line.

Against groups, fire will be effective if it is well regulated and directed as follows:

At 800 metres against a squad with closed ranks (5 metres front).
At 1,000 metres against a line having a half section front (10 metres).
At 1,200 metres against a line with section front (20 metres) or a section of artillery.
At 1,500 metres against company columns, or closed bodies of cavalry or artillery.

These limits are not fixed, and may be increased or diminished, according to the weather, the ease of adjusting the fire, and the shelter of the enemy.

Relative vulnerability of different formations in open ground, parallel to the line of sight.—At short ranges a kneeling man is little less vulnerable than a standing one. The vulnerability of a closed squad (12 to 16 men) will generally oblige it to deploy into skirmish line at a range of 600 or 800 metres. At short ranges deep formations are very vulnerable even with a small front. At the mid and greater ranges (400 to 800 and 800 to 1,500 metres) targets with narrow front are difficult to reach on account of the lateral deviation caused by atmospheric circumstances.

Extended lines permit a quick adjustment of the fire in direction, but at long ranges their vulnerability is slight because the dangerous zones are not deep.

Column formations with fairly large front, as company columns (20 metres), are very vulnerable.

The vulnerability of a line formation decreases faster than that of a deep one, as the range increases. At long ranges (800 to 1,500 metres) the vulnerability of closed columns is sensibly the same whether the men lie down, kneel, or stand.

Point of sight and elevations to use.—In battle it is generally best to aim at the foot of the target, for the line between the target and the ground is more clearly marked than the center of the target. (See also remarks on ricochet firing, p. 172.) Accordingly sights may be used as follows:

200-metre sight from 0 to 200 metres against men standing, kneeling, or lying.
300-metre sight from 0 to 300 metres against men standing or kneeling.
350-metre sight from 0 to 350 metres against men standing.
400-metre sight from 0 to 450 metres against riders.

For greater ranges a nearer approximation to the range is necessary. Troops of ordinary skill firing volleys or file-firing at any range over 400 metres form a beaten ground of about 100 metres on level ground. This constant depth of well-beaten ground permits an error of 50 metres either way in the choice of the sight, but with greater errors in the choice of the sight the results diminish fast. Errors in estimation, when they are short, admit of effective ricochets.

The combined use of several sights by a body of men against the same target increases the depth of beaten ground and decreases the density of the shot-grouping. The use of a single sight corresponding exactly to the range is always the most efficacious, but against a target in motion, or of some depth, two sights, differing by 100 metres, may be used. Bodies smaller than a section (50 men) should never use more than one sight simultaneously.

Adjustment of fire.—At short ranges (0 to 400 metres) the adjustment of fire is easy, the errors in choosing the sights cannot be great, and the flat trajectories compensate them. Taking the 300-metre sight, which is the sight for close action, the ground is well swept up to 350 metres, and is dangerous far beyond if the ground favors ricochets. The 400-metre sight may be used against standing men up to 450 metres, and is the best sight against cavalry at short ranges.

At greater ranges the estimation must be more exact, and allowance made for wind, &c.

Fire can often be adjusted by volleys watched with field-glasses, making a short estimate at first and increasing the range by not less than 100 metres.

In watching for hits, it must be remembered that half the shot should fall short in a well-adjusted fire. The presence of dust thrown up by the shot in front of the target is not a proof that the range is short, but on ground favorable for observation its absence is proof that the estimated range is too great. The beaten ground should begin 100 metres in front of the target at the mid and long ranges (400 to 800 metres and 800 to 1,500 metres). On rolling ground a depression in front of the target renders the observation of hits difficult, for the shot falling in the depression, their dust is not seen, and gives the idea that the bullets are over, when they really fall short. When observers are stationed on the flank, they must allow for parallax in estimating the fire as over or short.

General principles of the conduct of fire.—Fire is the preponderating element in battle. Its action must not be abandoned to individual initiative, which will result in nothing, and wastes ammunition, with the danger of being disarmed at the decisive period.

The duty of directing the fire falls upon the commandants of companies on the fighting line, and on the officers in the skirmish line.

(It is well to explain here that a French company numbers 200 or more men, and is divided into four sections. Squads number from twelve to sixteen men; there are four in each section.)

When in battle formation the company advances in two lines; two sections in each line with an interval of about 200 metres between the lines. When ready to open fire, the skirmish line is re-enforced, and finally absorbs the whole company.

The captain selects the objects at which to fire, the nature of the fire, and the fractions of his force to be put on the firing line during the preparatory period. He prescribes their method of advance according to the object to be reached, re-enforces the line as necessary, and leaving to his officers all the initiative necessary to carry out the duties assigned them, he sees that the fire does not deviate from the assigned direction, and tries to regulate it to the last moment. The chiefs of section name the sights to be used and the point of aim, the number of cartridges to use, and regulate the intensity and duration of fire. The chiefs of smaller units observe the sights used and the direction of fire, enforce the pauses in firing, and, in a word, see that orders are executed.

The conduct of fire requires coolness, decision, skill in estimating ranges, complete knowledge of the effects of the ground, of the ballistic qualities, and capabilities of the weapon.

The general principles regarding the direction of fire are the following: The force to be put in line depends on the tactical object, the number of cartridges necessary for decided results, and the time available for firing. Slow fire by single men gives no useful effects, but merely delays their advance. The re-enforcement should join the skirmish line as soon as it is time to begin firing. Sudden results from fire is one of the principal conditions of its efficiency. The moral influence of a certain result is greater as it is reached in a shorter time. The useful effect of musketry depends on accuracy and weight of fire, but results should be sought in accuracy and in the number of men firing rather than in individual rapidity of fire. Changes of objectives should be avoided until the results first attempted are obtained. Fire must be slow enough to be adjusted. It must be frequently interrupted by pauses of more or less length, to let the smoke clear, judge results, pass orders, and re-establish coolness. In volley firing these pauses occur naturally. In file firing the number of rounds should be fixed beforehand, *three or four at the most*, and fire should cease without orders. For fire to be so directed and regulated as to produce its full effect it is indispensable that it should stop and begin instantly at the will of the chief. On the defensive, pauses in the fire should occur while the attacking force is sheltered or lying down.

Employment of different kinds of fire.—The employment of volleys tends to maintain the control of leaders, facilitates the concentration of fire, permits the rectification of aim by watching the hits, and affords means of controlling the expenditure of ammunition.

Squad volleys should be executed as long as the men can be kept in hand by the leaders.

On the offensive, volley firing belongs to the long-range period of action. It cannot be executed by the attacking troops, for it requires immobility and comparative security, which is incompatible with a vigorous offensive. This fire should be carried out by special troops; by the reserves on flanking or commanding positions, or by troops making a demonstration. Volley firing must not be demanded from the fractions in close order which re-enforce the skirmish line at short ranges, unless they are sufficiently sheltered. After carrying a position, volleys are best adapted for following up the enemy and getting the troops in hand.

On the defensive, sheltered troops should fire volleys as long as possible. Even at the final assault volleys will be effective against an enemy advancing unprotected and not firing. Volleys in closed ranks in general should not be executed by larger bodies than sections.

Slow, well directed, file firing gives results a little better than volley firing; but it renders fire discipline and the regulation and concentration of fire more difficult. Rapid fire at 200 or 300 metres owes its value only to the flatness of trajectories. It cannot be avoided when the final crisis arrives. Its duration will be short and will be immediately followed by the solution.

Indirect fire requires previous exact knowledge of the topography. It can seldom be used on the offensive, but more often on the defensive. In sieges both the attack and defense may obtain great service from it.

Distances for opening fire.—The range at which fire should be opened depends on the facilities for adjusting it, the nature of the ground, the vulnerability of the objectives, and their tactical importance.

Fire at long range may confuse a body of men, delay its entrance into action and afford chances of future success, or render difficult the occupation of a decisive point, such as a bridge, cross-routes, or some passage necessary to the enemy, but its effects are rarely decisive. Its use calls for a sound and well-considered appreciation of the situation, and should not be left to the leaders of all grades. In general, it belongs to battalion-commanders and captains to determine the target and the time for and duration of long-range fire. It is, above all, at short ranges that plenty of ammunition and muskets are needed, in order to have great superiority at the time when the effects of fire are surest and most powerful. The artillery should prepare the attack at long ranges; infantry can seldom assist it.

The premature opening of fire on the fighting line may prolong the fight, and consequently lead to the exhaustion of ammunition and the weakening of the moral energy of the attack. On open ground the skirmish line should open fire at the mid-ranges (400 to 800 metres); on broken and covered ground it may reach the short ranges (under 400 metres) before opening.

On the defensive, more often than on the offensive, will be found occasions for the effective use of fire at the mid and long ranges upon large targets, principally artillery. This distant fire of the defense may also cause the attacking troops to deploy too early and waste ammunition at long range.

Influence of the ground upon the effects of fire.—This subject is considered in two parts—first, the influence of the enemy's ground upon the effects of one's own fire; second, the influence of one's own ground upon his fire and that of the enemy. The first part consists of simple deductions from the discussion on fire on inclined ground (pp. 169–172), which it is scarcely necessary to reproduce. The second part may be examined a little more fully.

The advantages and disadvantages of the occupation of sloping grounds depend greatly upon what has already been said in regard to fire to which the troops occupying them are subject; they depend also upon the efficiency of fire which can be delivered from them.

The defense.—Ground most favorable to the defense offers in front of the firing line a glacis giving an open field of fire of great extent, sloping gently towards the enemy. The greater the slope behind the crest the better the rear echelons will be protected. For to sweep steep slopes the range must be great, thus losing in accuracy and efficiency.

The line of defense in front of the crest should not be a continuous one. There should be intervals without fire which will not draw that of the enemy. Behind these intervals should be the supporting troops; they will thus be largely sheltered from fire aimed at the skirmish line, and near the places they will most probably occupy when called to reenforce the firing line.

Ground sloping below the line of sight.—Troops behind the line of defense must not think themselves safe because invisible to the enemy. If unsheltered they should form with narrow fronts, well in rear of the first line, when the enemy fires at long range, and advance gradually towards the crest as the enemy approaches, so as to avoid his short-range fire. This forward movement likewise satisfies the tactical requirements of the action. On ground inclined below the line of sight the observation of the fall of bullets will show where the reserves and supports may best be placed; for the striking points depend on the slope of ground and not on the aim of the firing force, which cannot see its enemy. In choosing a second line of defense, when it is not defined by the nature of the locality, regard should be paid to the ranges at which it is possible well to sweep the slopes of approach in front of the crest (of the first position).

Ground sloping above the line of sight.—Ground of this nature favors the action on the skirmish line. Column and flank formations are particularly valuable. Line formations with intervals are preferable. The distances between the successive echelons may be diminished as the slopes are greater. The lines behind the skirmishers will usually suffer only from fire directed specially at them.

All accidents of ground should be utilized for shelter if no artificial shelter is available. The best protection will be found in a rapid, uninterrupted advance, for in rapidly crossing the diminished dangerous zones, a single rush will take the line beyond the effects of the enemy's previously adjusted fire. It must be noticed that such ground has the disadvantage of displaying all one's dispositions to the enemy.

(This discussion of the effects of ground on fire is equally applicable to artillery.)

MUSKETRY INSTRUCTION IN THE GERMAN ARMY.

The following remarks upon the German "Shooting Instructions for Infantry" are taken from the Revue Militaire de l'Etranger for 1885 (volume 27), an official publication of the French war department.

The first chapter deals with targets (see Plate 1). The stroke-target is 120 centimetres square, and is divided by the vertical black stroke. The middle of the target, 40 centimetres wide, is called the "man's width." The black ring numbered 9, with its white centre, is called the mirror.

The school-target is of the same size. The stroke is narrower and does not pass through the mirror. The rings, concentric with the mirror, are numbered from 1 to 8, the black of the mirror being 9 and the white centre 10.

A hit on the mirror or on any of the rings scores the number of that division.

The figure-target is a man's figure, drawn within a rectangle of 170 by 40 centimetres. Parts of the figure target are placed on the school target for some practices, as shown in the figure.

The section-target is employed for collective practice at long ranges. It is 170 centimetres high and of any required width, divided into vertical bands 40 centimetres wide, alternately white and colored.

The second chapter deals with the personnel in charge of target practice, and recommends the instructors to become acquainted with the ability and intelligence of their pupils; to encourage among them a taste and liking for target practice, and by all means to avoid discouraging them.

The third chapter deals with the bases of the method to follow in instruction. The preparatory exercises are similar to the French, and before firing ball cartridge there is practice with reduced charges. Importance is laid on teaching the men to sight quickly in all positions.

There are three kinds of target practice: School practice, battle practice, and instruction practice. The men are divided into three classes. Recruits join the third class, passing to the second after a year, if they qualify, and at the end of the second year they pass to the first class, if they qualify for it.

School practice.—Third class men in each of sixteen exercises are required to make a certain score (varying for each exercise) in a string of five shots. The exercises differ in the position, in firing at will or by order, in the presence or absence of a rest, in the range, and in the targets, which are the stroke-target, the school-target, figure-target, and vanishing target. The ranges are all 200 metres or less, except one at each of 250, 300, and 400 metres. In order not to discourage backward men they are not held indefinitely at a difficult exercise until it is executed, but after completing the series, the difficult one is tried again with the unexpended allowance. Those men pass to the second class, who have executed the last ten exercises with 70 cartridges or less. (They may be done with 50 only.) The second class executes 12 exercises, similar to those of the third class, introducing an exercise with a running target and neglecting the fire by order. The ranges for all exercises are 200 metres or less, except one at each of 250, 300, and 500 metres. Men executing the last nine exercises with 63 cartridges less or pass to the first class. The first class executes 12 exercises, similar to those of the second class, all ranges being 200 metres or less, except one at each of the 250, 300, 400, and 600 metres ranges. Non-commissioned officers twice executing the conditions for the first class, form a special class. It must be remembered that the German rifle has a leaf sight for ranges of 400 metres and more, a flap sight adjusted for 350 metres, and a fixed sight adjusted for 270 metres. As the conditions of each exercise require certain parts of the target to be hit, as so many mirrors, so many rings, etc., and as the ranges do not coincide with the adjustment of the sights, it is evident that the choice of sight and point of sight must be considered and properly selected, in spite of the very short ranges. For example, success in the second exercise for the third class requires the following hits at 100 metres range, firing five times at the stroke-target; five shots in the man's width, two in the stroke, and three in the mirror. Hits on the stroke within the mirror count as both stroke and mirror. In the third exercise for the third class the range is 100 metres and the school-target is used. In five shots there must be five man's widths, three mirrors, and forty rings.

Battle practice.—Battle practice follows school practice, and is meant to teach men what they will be required to do in war. It is divided into two parts, individual practice and group practice, 10 rounds being allowed for the first and 20 for the second. The firing ground should be at least 3,000 by 1,000 or 1,[illegible]00 metres.

In individual practice the figure-target and its varieties are used, as well as disappearing and running targets. They are placed at unknown and frequently changed ranges, never over 450 metres. Each man fires at will, choosing his position and sight.

Group practice completes the instruction in battle practice. It is intended to exercise officers and non-commissioned officers in directing the fire, and to improve fire discipline among the men. The exercise must be carried out by bodies filled out to the war size (companies, 250 men; zugs or sections, 80 men). Tactical themes will be assumed to bring out the effects of fire on both the attack and defense. Section targets are used for these exercises, and after finishing the exercise the men are marched to the targets, reminded of the phase of battle assumed, and shown the results.

Instruction practice.—Instruction practice has for its object to show clearly to the men the ballistic qualities of their weapon and the effects of mass fire, and the exercises are carried out by skillful marksmen under the most favorable circumstances.

Ballistics of the rifle.—There are five exercises devoted to showing the ballistic qualities of the rifle:

(1) Determination of the mean point of impact of different weapons.

(2) Demonstration of the size of the shot group at different ranges.

(3) Representation of the trajectories by the ordinates, using the fixed and flap sights.

(4) Demonstration of deviation owing to fixing the bayonet.

(5) Fire from the shelter of a trench against small moving targets, themselves sheltered by a parapet and sacks of earth or other artificial cover.

The first exercise is carried out by a good shot firing 5 rounds from a rest at 100 metres range with each of three rifles, one of which is well sighted and the others poorly, using the same elevation and aiming at the same point. It is pointed out that each gun makes its own shot group, and the lesson is drawn that each man must know his weapon to make the best use of it.

In the second exercise a skillful marksman fires 25 rounds at each of the ranges of 200, 250, 350, 450, and 600 metres at one or two section targets placed together. The aiming point is marked beforehand on the target. The size of the shot groups shows the accuracy of the rifle at different ranges.

The third exercise is carried out by a man firing two series of shots at section-targets at ranges increasing by 50 metres from 50 to 350 metres. The first series is fired with the fixed (270 metres) sight, and the second with the flap (350 metres) sight, the point of sight in both being the foot of the target. The mean point of impact at each range shows the mean ordinate of the trajectory for that sight and range. The mean points of impact are then marked by red disks, and the tagrets of each series placed parallel to each other with the proper intervals, thus showing plainly the trajectories and their heights.

In the fourth exercise a good shot fires 7 rounds with fixed and unfixed bayonet at 200 metres, and the different positions of the mean point of impact shows the deviation owing to the bayonet.

The fifth exercise is carried out by a group of skilled marksmen, who in the presence of their comrades fire at 200 metres range at silhouettes placed behind a rampart of bags of earth, in which are loop-holes of 10 centimetres in height by 5 centimetres in width, and through which the bullets must pass. The men not firing watch results and indicate the necessary corrections. The instructor points out the necessity for good observation to make the proper correction quickly.

Effects of fire.—The demonstration of the effects of collective fire includes three exercises, namely:

(1) Representation of the efficiency of collective fire on a given portion of the beaten ground, using one or two sights.

(2) Firing by day under the conditions of a siege.

(3) Firing by night, using a rest.

The first exercise is carried out by a group of 10 to 25 men lying down, aiming at the foot of the target, using the 700-metre sight, and firing at will 100 rounds at six targets, whose ranges vary by 20 metres from 640 to 740 metres. Afterwards using the combined sights of 650 and 750 metres, the group fires 100 rounds at six targets whose ranges vary by 40 metres from 600 to 800 metres. From the marks on the targets may readily be deduced the density of the shot groups at any part of the beaten ground.

For a demonstration of siege-firing groups placed in shelter trenches fire at ranges of from 400 to 700 metres against head-targets (35 centimetres high) placed on embankments, representing heads looking over a parapet.

In the night practice, firing groups are placed at ranges of from 200 to 400 metres, and fire at section targets or silhouettes of different sizes placed side by side.

The men are exercised during the day in building rests on which the arms are placed to insure a fixed aim, and they fire by day from these rests to see what allowance for jump must be made under these circumstances, so as to make due allowance during the night firing. Finally the rests are placed at night-fall and the fire begins after dark.

The annual practice is closed by an examination practice, of which battalion reports are forwarded to the Emperor.

Rewards, &c.—Rewards consist of prizes and badges. The prizes are silver medals of four classes, worth from 1 to 2 dollars each, and the badges are devices to be worn on the coat. Each battalion receives fourteen prizes, two for the non-commissioned officers of the battalion and three for the privates of each company. One of the prizes for non-commissioned officers goes to the man of the special class who has fulfilled the conditions with least cartridges, the other to the man in the first class who has similarly fulfilled the conditions of that class. One prize in each company goes to the man in each class who has fulfilled the conditions of the class with the least cartridges. Twelve badges are annually issued to each company—six to the first class, four to the second class, and two to the third class—recipients being those who have fulfilled the conditions with the fewest cartridges. The non-commissioned officers of each battalion likewise receive twelve badges, provided that no one receiving a badge has done worse than soldiers receiving none.

Conduct of fire.—In an appendix are given some directions regarding the use of sights and the conduct of fire. The German regulation considers 450 metres as the limit for individual fire, except in special cases where the range is exactly known, when the limit is 600 metres; at greater ranges collective fire must be used.

In collective firing the use of combined sights is recommended where the range is not precisely known. Between 400 and 600 metres two sights differing by 50 metres may be used against fixed targets, and between 600 and 800 metres the sights should differ by 100 metres. Against rapidly moving targets beyond 400 metres several sights differing by 100 metres should be used.

1,200 metres is considered the limiting range of useful results from collective fire; in general, German infantry fire will cease beyond this range except in special cases.

In regard to the important element of fire direction, special weight is laid upon the necessity of choosing a place for deployment, permitting the utilization of all the power of the fire, as well as of making a wise choice of the target, of the sights, and nature of the fire to use.

Rapid fire is condemned as leading to disorder, and an intermittent fire on the skirmish line by firing a given small number of cartridges and ceasing promptly at the whistle call is preferred.

Volleys will be used only in the beginning of an action, and should serve to ascertain the range by watching the ricochets. The appendix closes as follows:

> It will often happen during action that the control of fire escapes from the company and section officers; it will then be the duty of the non-commissioned officers, or even of intelligent and energetic soldiers, to cause the groups near them to fire wisely. Often at short ranges even this will be impossible, and success will depend only on the training of the men. Hence it is necessary to train every man so that he may act without direction and make a proper use of his weapon.

Judging distance.—In regard to judging distance, preference is given to simple judgment by the eye after having become acquainted with certain standard distances to serve as units and also with the appearance of a man at different ranges.

Men learn to judge up to 400 metres, and non-commissioned officers and officers up to 1,200, the first being the limit for individual and the second for collective fire. The average error in either direction of the mean estimation of several practiced observers is about one-eighth the range.

Remarks.—In examining the German method there are several noteworthy points:

(1) The height of the 400-metre trajectory (1.63 metres) is that of a man. If with this sight aim is taken at the feet, a man will be hit at any less range. At less ranges choice must be made between the 270-metre sight and the 350-metre sight, as the Germans prefer to train their men to make a judicious selection between two sights and of the point of aim, rather than to have them fumble with a sliding leaf at the critical instant of close action.

(2) The Germans do not think it worth while to spend much effort in training men to shoot well individually at ranges over 400 metres, and beyond 600 metres such effort is thought useless, as appears from the relative expenditure of ammunition at different ranges in school target-practice.

(3) The second part of the instruction firing shows what great importance is attached to mass firing at ranges over 400 metres.

MUSKETRY INSTRUCTIONS OF THE ITALIAN ARMY.

Some particulars in regard to firing given in the Italian army regulations may be interesting.

Effects of range on efficiency of fire.—If it is assumed that the useful effect obtained by a company of infantry firing at any target whatever at a range 1,500 metres (1,650 yards) is unity, then at 1,000 metres the expenditure of the same quantity of ammunition against the same target will produce an effect of 3.5; at 500 metres, the effect will be 10; and at 200 metres, 35.

Vulnerability of different formations.—If the efficiency of fire against a company in closed line in double rank, standing, is called 10, on deploying the line in skirmishing order, at the same range and in the same position, the efficiency will be only—

6 if the line is dense (intervals of 0.7 metre);
3 if the line is the ordinary one (intervals of 1.4 metres);
1.5 if the line is thin (intervals of 2.8 metres).

If the line is kneeling the effects of fire are 70 per cent. of those against the same line standing; that is, the efficiency is 7 against a closed line, 4.3 against a dense line of skirmishers, 2.1 against the ordinary line, and 1. against the thin line.

If the line lies down, the effects obtained will only be one-quarter of those obtained against the standing line, namely: 2.5 against the closed line, 1.5 against the dense line of skirmishers, 0.8 against the ordinary line, and 0.4 against the thin line.

If the line in any of the three positions is sheltered by parapets of suitable corresponding height, the effects will be reduced to one-half of those obtained when the line is unsheltered.

If the hostile infantry appears in column of sections, facing the firing troops, the effects of fire will be much greater than against the same force in closed line.

At the long ranges the column formations are two or even three times as vulnerable as the line formations. At short ranges the difference is less; but at less than 500 metres it may be admitted that the losses of troops in column will be 50 per cent. greater than that of troops in line.

The losses of a formation in column offering its flank to the fire will be a little less than if facing the fire.

The relative losses vary in the same proportion when troops are exposed to artillery fire.

Effects of rapidity of fire on accuracy.—The rapidity of fire has no great effect upon the useful effect produced. It may be assumed that with men who have had some little training, a fire at the rate of four rounds per minute will produce nearly the same effect as the slower expenditure of the same amount. When the rate exceeds four rounds a minute the fire becomes a little less precise. If the rate is six rounds a minute the effect produced by the consumption of a given amount of ammunition is about nine-tenths of that produced at a rate of four rounds.

Infantry, either in close or skirmishing order, firing at will with good aim, readily expends three rounds a minute, and in battle-practice it is difficult to fire less than two to three rounds a minute. It is, therefore, better to economize ammunition by pauses in the firing, than to try to fire slowly and continuously.

Use of the magazine.—The magazine will be used only (1) to prepare for the assault of a position; (2) to repulse an assault; (3) to resist a cavalry charge; (4) to follow up a retreating enemy. *In all these cases the range must be less than* 300 *metres. If the enemy is lying down or partially sheltered, the range must be less than* 200 *metres.*

MUSKETRY INSTRUCTION IN THE UNITED STATES NAVY.

Instructions in regard to this matter are very brief.

The following directions are extracts from the Ordnance Instructions of 1880:

All the men in the ship must be encouraged to practice with the single stick and bayonet, and they must be frequently exercised at target practice with pistol and rifle. The officers should also be practiced in the use of the sword and target firing.

The whole crew is to be exercised in the use of the rifle, pistol, and sword; in the principles of aiming, and in firing at a target with small-arms.

He (the captain) will cause the boats' crews to be exercised * * * * in the use of * * * * small arms under the various circumstances likely to arise in such service.

The Navy Ordnance Pocket Manual, 1881, contains further directions:

All officers are required to practice with revolvers, and reports of their practice must be made upon the proper forms to the captain.

Officers are informed that "Wingate's Manual of Rifle Practice (now replaced by Blunt's Manual) will be furnished to ships, and officers will find therein a higher instruction than ordinarily comes within their reach."

Ammunition should be expended in firing at any kind of target rather than postpone practice until a shore range can be obtained.

Small-arm ammunition may be liberally expended in target practice.

(A recent circular requires that the quarterly expenditure for small-arm target-practice shall not be less than 25 rounds in the first year of the cruise; 20 in the second and 15 in the third.)

Then follow directions regarding the size of the targets to be used at different ranges; their divisions are similar to those of the Army but circular; and the method of scoring is that of the Army. The forms of reports and returns are also given.

Employment of small arms in action.—In regard to the stations and duties of small-arm men in action, the Ordnance Instructions prescribe that—

Rather more than half the men composing a gun's crew will be riflemen, and will usually form two divisions. Topmen and part of the powder division are also armed with rifles. Part of this force is composed of men selected for their skill as marksmen; they form the first division.

When called away, the riflemen will repair on deck to the place of assembly with their arms.

The navigator commands the whole body of riflemen, including machine guns and howitzers.

When the hostile vessels approach within suitable range the marines should be called away as sharpshooters; and when they require assistance they should be re-enforced by the first riflemen. The body thus assembled is sufficient to maintain a sharp contest and its fire should be directed against officers, spongers, loaders, gun-captains, topmen, marksmen, and other important persons on the enemy's ship. The men in the tops should be similarly employed.

When boarders are on deck the riflemen and marines fix bayonets.

The ships being fouled or otherwise secured together, the order may be given to board. The boarders shall gain the enemy's deck * * * * * and must be followed *very* closely by strong supporting bodies of riflemen, who shall cover and defend them, directing their fire principally against the riflemen of the enemy. The remainder of the riflemen and the marines must close somewhat towards the point of attack, being held well together so as to act as effective supports in case of repulse.

Those topmen who are supplied with hand-grenades will use them against the enemy while the foregoing operations are in progress.

While boarding is going on the topmen should endeavor to drive the enemy from his tops and may take possession of them.

If the boarders are driven back, they will rally on the flanks of the marines and the riflemen, taking care to get quickly out of their line of fire. The latter bodies having been sufficiently concentrated while the boarding was going on, receive the enemy with a heavy fire; one or both charging him if he should gain the deck.

If the enemy approaches with the intention of boarding, as soon as his men begin to collect, the marines and such riflemen as are necessary should be called away and open fire from favorable positions.

If the enemy falls alongside, such portions of the side as he may be able to assault must be covered by the marines and riflemen with bayonets fixed and in one or two ranks, according to the space and number disposable. They should generally be formed in the engaged gangway near the midship line, the boarders being on their flanks and rear, pistol in hand.

Any commanding positions in rear, such as boats, booms, &c., should be occupied by strong detachments of small-arm men under active officers.

Those posted in the tops should maintain a vigorous fire.

If any considerable body of the enemy gains the deck it must be charged by a suitable detachment, after having received a heavy fire from the whole body.

In small-arm contests the fire as a rule should be "at will," but the whole body of small-arm men should not be permitted to empty their pieces when the first of the enemy's boarders appear. The fire shall then be delivered "by file," by volleys in subdivision, or by every other man. Volleys by subdivision resorted to just before a charge would be effective.

In a close contest on a ship's deck it might be at times that a sword would become a more effective weapon than the musket and bayonet. In such a case the swords of the boarders shall be brought into full play, and the sword bayonet shall be unfixed and used.

Remarks.—In regard to musketry instruction we find no rewards offered for skill, nor directions of any kind, but the naval official publication merely recommends the army system, with the assurance to officers who care to employ it that it will redound to their credit.

In regard to the tactical employment of small-arm fire in battle we find that the directions prescribe such a use of small-arm fire as has always been made since a very early date, with the single exception that the present instructions contemplate a closer support of the boarders than was possible with the older type of small arm.

The entire subservience of our present instructions to early practice, however, is clearly shown in the paragraph already quoted, directing that "all the men should not be permitted to empty their pieces when the first of the enemy's boarders appear."

It is worthy of note that while the "instructions" contemplate boarding and the use of the bayonet, bayonet practice has not been required in the service, although under many circumstances the bayonet may prove a better weapon than the cutlass. The bayonet, however, is no longer a service weapon in the United States Navy, although still retained by the English and French navies, the latter of which was the first to adopt the magazine rifle, which we believe to be an ample substitute.

MUSKETRY INSTRUCTION IN THE BRITISH NAVY.

[From Rifle. and Field Exercises and Rifle Practice Instruction for Her Majesty's Fleet.]

The musketry instruction in the British navy is of two classes, that of the gunnery ships and that of sea-going ships.

Annual course, gunnery ships.—The instruction in musketry is divided into preliminary drill and practice.

Under the head of preliminary drill are comprised the following subjects: Cleaning arms, theoretical principles, aiming drill, position drill, preliminary firing, and judging distance drill.

Practice consists of:

(1) Ball practice; including firing singly, firing by volleys, independent firing, firing in skirmishing order, and firing at moving objects.

(2) Judging distance practice.

There are two courses of musketry instruction on the gunnery ships, a long and a short course.

The long course for officers, petty officers, and seamen is completed in eleven days; of which the first five are devoted to preliminary drills (four hours per day), and the last six to practice; of which one day and a half is given to judging distance practice and the rest to ball practice. In the latter 90 rounds are expended in firing singly and in independent volley and skirmish firings. The best shots expend 15 rounds more in practice at moving objects.

The short course is six days long, of which two days (eight hours) is given to preliminary drills and four days to practice, including ball practice and judging distance practice.

Annual course for sea-going ships.—All working petty officers and seamen in the sea-going ships are annually put through a course in musketry. This course differs from that of the gunnery ships in omitting all judging distance drill and practice and volley firing and in expending only 60 rounds, with 15 extra rounds to marksmen and first-class shots for practice at moving targets.

A minimum of twelve hours at preliminary drills is required from men who have not been previously instructed, and of eight hours from those who have been previously instructed before proceeding to ball practice.

The instructions in regard to cleaning arms, theoretical principles, aiming and position drills, are similar to those already described, and need not be recapitulated.

The preliminary firing is with blank and ball cartridge, and is merely to teach the men to stand up to the recoil and accustom themselves to the discharge.

Sub-calibre practice.—The object of this exercise is to admit of a large amount of practice with rifles being carried out on board ship, and accordingly it is to supplement the annual course of preliminary drills. It is carried out at a range of 10 or 15 yards, with Morris's aiming-tubes, ammunition and targets, supplied in the following proportions: Tubes, 10 per cent. of the rifles on board; paper targets, 250 per tube per annum; box-targets, 1 to every 2 tubes; ammunition for practice, 100 rounds per annum for each man of the complement. The tube is a short barrel, calibre .22, mounted in the rifle barrel so that the cartridge is fired and extracted in the same manner as the service-cartridge. The ogival-headed leaden bullet weighs 37 grains and the charge is 3¼ grains.

The paper targets are pasted on the fronts of the box targets, which serve to catch the bullets. To prevent injury to the ship's fittings, by shots missing the target, a few sand bags made of old canvas should be built up around the box. If any inconvenience is felt from the splashing of the lead, it may be entirely stopped by covering the front of the box by old canvas to which the paper targets are pasted.

Judging-distance drill.—In judging-distance drill men are placed as points for observation at various ranges, and the instructor indicates the peculiarities of appearance at the different ranges up to 1,200 yards.

Targets.—The targets are of iron, 2 by 6 feet, with the faces cut into 6-inch squares.

For 100 and 200 yards (third-class target), 2 targets are joined, having a 1-foot circular bull's eye and 3-foot centre.

For 300 and 400 yards (second-class target), 3 targets are joined, having an 18-inch bull's eye and 3-foot centre.

For 500 and 600 yards (first-class target), 4 targets are joined, having a 2-foot bull's eye and 4-foot centre.

The target for volley and independent firing is formed of 6 targets with a 2-foot black horizontal stripe across its middle. Scoring is as follows: Bull's eye, 4; centre, 3; outer, 2 points.

Ball practice.—The annual allowance for sea-going ships is 40 rounds for individual firing, 10 rounds in independent firing, and 10 in skirmishing order. Those who qualify as first-class after 40 rounds of individual firing, fire 20 rounds at 500 and 600 yards; 10 at each. For the long course in gunnery ships the allowance is 60 rounds for individual firing; 10 for volleys, 10 for independent firing, and 10 for skirmishing firing.

Besides the above, marksmen and first-class shots on both sea-going and gunnery ships will expend 15 rounds in practice at moving targets when such are available.

Firing is divided into three periods. In the first period, practice is carried out at 100 and 200 yards, 10 rounds at each range. Any one failing to make 15 points at 100 yards is put back to undergo further preliminary drill, and cannot take any money prizes.

In the second period the firing is at 300 and 400 yards, 10 rounds at each, and after concluding it, the men who have a total of 100 points in both practices form a first class; those with 60 points form a second class, and those with less than 60 points a third class.

In the third period the men practice at 500 and 600 yards, 10 rounds at each range, men making 45 points being raised a class.

At the conclusion of the practice the points obtained by each man are to be added together and the men finally classed as follows: Men obtaining 165 points and upwards, classed "Marksmen;" men obtaining 140 to 164 points, "1st Class;" men obtaining 100 to 139 points, "2d Class;" men obtaining less than 100 points, "3d Class."

Volley firing is for gunnery ships only. The range is 300 yards, front rank kneeling. The target is formed of six targets placed together, with a 2-foot black horizontal stripe across the middle. Hits and ricochets count 4 on the stripe and 2 points on the rest of the target.

In independent firing 10 rounds are expended at the same range as before, with the same position, target and value of hits.

In skirmish firing 10 rounds are fired while advancing from 400 to 200 yards, and retiring again until the ammunition is expended. Each man judges his own distance, arranging his sight accordingly. Each file (two men) has its own target. The target is 2 feet high by 6 feet wide, with a 2-foot black square at the middle. Hits count 4 points on black and 2 points on white.

Judging-distance practice (*for gunnery ships only*).—Men are placed at different ranges in various positions, and the members of the class are required to estimate the ranges, which are then measured. The practice is divided into three periods, each consisting of eight estimations. The points allowed are as follows:

First period, distances are between 100 and 500 yards. Within 25 yards, 2 points; within 50 yards, 1 point.

Second period, distances are between 505 and 1,000 yards. Within 25 yards, 2 points; within 50 yards, 1 point.

Third period, distances are between 505 and 1,200 yards. Within 25 yards, 2 points; within 50 yards, 1 point.

At the conclusion of the practice those having 36 points and over are formed into a first class, those having 28 points and over into a second class, and those having 20 points and over into a third class.

Rewards.—To the best shot in the ship: For ships having two hundred men or more exercised in musketry, badge and £2.10*s*. Ships having one hundred and twenty or more men exercised in musketry, badge and £2.

To the best shot in each company (forty to fifty men) provided he obtained one hundred points in firing the forty rounds allowed, badge and £1.

For marksmen to the number of 6 per cent. of the whole number firing, provided that it is not less than one company of forty men, prizes of 2*s*. 6*d*.

In the gunnery ships a prize of 2*s*. 6*d*. is awarded to the best judge of distance in each company of at least forty men. (This prize is not mentioned in the latest edition.)

Badges are to be worn one year only, unless qualification is renewed.

Use of small arms in action. (From Gunnery Manual.)—A certain number of marine infantry, depending on the size and armament of the ship, should be told off as marine small-arm men. When machine guns are mounted round the upper deck, there is less need for marines as small-arm men and they are more wanted at the guns.

A certain number of the best rifle shots among the seamen should be selected and stationed in the tops; in large ships, at least six in the fore and main, and four in the mizzen tops. When a machine gun is mounted in the top, these men will work it, falling back on their rifles in case of accident to the gun.

All the rifles are to be issued. All the upper deck guns' crews, top riflemen, and boats' crews (except coxswains and bowmen) should be armed with rifles, the remainder being divided among the battery guns' crews.

Fittings in various parts of the upper deck should be provided by means of casks, planks, mess tables, etc., for the marine small-arm men, to fire from over the netting, and for the other riflemen when ordered.

The boarders in large ships are organized in three divisions, including both riflemen and cutlass men. Each division is assigned a place of muster to which the men repair when called. The upper deck parties and all marines fall in with rifles, the remainder with cutlasses and pistols.

In boarding, the riflemen should be used to cover the attack of the cutlass men. They should be taught to occupy every available space, keeping together by guns' crews and as much as possible under cover.

It should be remembered that from the very nature of the exercise it is impossible to drill at boarding in the same way as at the great guns. All, therefore, that can be done as a gunnery exercise consists in organizing the boarders and placing them in position; the real exercise to cultivate the necessary dash and agility will be found in sail and spar drill.

Machine gun and rifle fire will probably play an important part in future naval engagements. Speaking generally, there may be said to be four principal objects at which this fire may be directed:

(1) Exposed men on the upper deck, including helm party.
(2) Enemy's machine guns.
(3) Battery ports.
(4) Conning tower.

In reviewing the system of musketry instruction we see that it is merely the army system incompletely carried out. The army field firing is lacking. Volley firing is carried out only on gunnery ships, and this is almost useless, for volley firing requires a number of men accustomed to exercise together, but as the men from the gunnery ships are transferred individually to other ships, their skill in volley firing is lost by the transfer.

The employment of riflemen in action is very similar to that of our own service.

An article on Musketry Instruction Afloat, in Vol. 29 (1885), of the Journal of the R. U. S. Institute (p. 127), by Lieutenant Lowry, R. N., gives a good idea of the present system. This writer says:

> Our system of instruction differs from that of the army in the following particulars: 1. Only seamen gunners are put through the whole course. * * * Many men never go to the gunnery ships, * * * and some actually complete their first 10 years' service without any careful musketry instruction beyond that received as boys. * * * In our present system of musketry instruction we have now—
>
> (1) Individual instruction up to 600 yards for most men, carried out with more or less care.
>
> (2) A very little judging distance *on shore* for men passing through the gunnery ships. * * *
>
> (3) A little volley and independent firing on shore once a year under very unreal conditions.
>
> (4) In gunnery ships and in a very few sea-going ships ten rounds of skirmishing per annum, on shore, under conditions as to movement and range slightly resembling those of real action.
>
> (5) Directions to exercise top riflemen at general quarters, but no systematic plan of teaching them; as a matter of fact, few but the individuals actually stationed in the tops are so practiced.
>
> (6) Directions to exercise stokers and idlers when opportunity occurs. The duties of these men render it very difficult to get them to fire at a fixed target in most sea-going ships.
>
> (7) A very little firing from boats in a small percentage of ships.
>
> (8) Only about 75 per cent. of our complements are trained in musketry at all, under the most favorable circumstances.

MUSKETRY INSTRUCTION IN THE FRENCH NAVY.

[From "Manuel du Marin Fusilier."]

General plan.—All men, without exception, on shipboard, in divisions (the naval forces in the five arsenals), or shore stations, are to be instructed in small-arm firing and are exercised in the management of their weapons.

On shipboard, with a view to the instruction prescribed above, the crew is divided into three classes.

(1) Men armed with rifles when at quarters, forming the body of ship's riflemen.

(2) Men belonging to the landing force.

(3) Men not armed with rifles in action.

There are three corresponding degrees of instruction.

The first is applicable to the entire crew and includes: (1) the first part of the school of the soldier and the firing instruction; (2) individual target practice, always carried out on shore unless absolutely impossible. to do so, when it is carried out on shipboard at floating targets.

The second degree of instruction is applicable to the ship's riflemen, and besides the above includes: (1) the manœuvres and movements of riflemen during action on shipboard; (2) target practice from stations at quarters, including top and boat fire; (3) handling the revolver cannon with target practice.

The third degree of instruction is applicable to the men of the landing force, and besides all the above includes: (1) the school of the company; (2) the carrying out on shore of supplementary target practice; (3) outpost duty on shore and summary notions in regard to field intrenchments; (4) the school of the battalion.

The third degree of instruction will not be considered in this article, although it is very full.

Organization of riflemen.—The riflemen are divided into "deck riflemen" and "re-enforcing riflemen." The deck riflemen are taken from among the best shots of the "rated riflemen" (*fusiliers brevetés*) and they are not stationed at guns. They are divided into squads of from six to twelve men each, commanded by a petty officer. A chief petty officer commands two squads. Two men in each squad provide ammunition. Each squad is assigned to a certain part of the deck on the side manned or on one side when both are manned. Squads are numbered from forward, aft.

The fighting topmen carry on the top small-arm fire. The men in each top provide ammunition.

The re-enforcement of riflemen includes men armed with rifles not belonging to the deck parties. It is organized into two equal divisions, starboard and port, and re-enforces the deck riflemen at the captain's order. It is divided into squads corresponding to those of the riflemen, and each squad of the re-enforcement supports more particularly the corresponding squad of riflemen. The deck musketry is commanded by a watch officer, who also commands the landing force. He may be the gunnery officer, or else has the gunnery officer under him, besides a variable number of officers, according to the force of the riflemen.

The re-enforcement is under the battery officer while below, and passes under the command of the officer commanding the riflemen when it is called on deck. The petty-officers see to the execution of the officers' orders, correct noiselessly any mistakes made, preserve order and silence, and watch carefully the consumption of ammunition.

Instruction.—On board each ship the musketry instruction of riflemen is directed by the watch officer commanding the riflemen, aided by the musketry instruction officer; the instruction of the rest of the crew is under the musketry instruction officer, who is under the executive officer. The instruction of the men is carried out by petty officers under the supervision of the officers.

In instruction the following principles are observed:

Less than thirty lessons of one hour each in the school of the soldier will produce insufficient results.

Unless the lessons follow each other closely with the same men under the same instructors the best results will not be reached. The first part of the school of the soldier, which is taught to all the men in the service, corresponds to the school of the soldier in our own army, and teaches the men to march, dress, and face so that they may move about the decks in a military manner. It further includes dismounting and assembling the rifles, the manual of arms, bayonet exercise, and the preparatory firing exercises.

The musketry instruction includes four parts: (1) Preparatory exercises and theoretical principles; (2) sub-calibre practice; (3) target practice; (4) judging distance.

The preparatory exercises and theoretical principles need no description, for they are similar to those of the French army and other services.

Sub-calibre practice.—The sub-calibre practice corresponds to the gallery practice of the U. S. Army. It is carried out by inserting a small barrel of the exterior dimensions of the service cartridge shell into the chamber of the rifle. A small central percussion cartridge is fired from this barrel. The charge is 28 grains of powder, and the mushroom shaped leaden bullet weighs 108 grains.

In exercising, an assistant places the stem of a bullet in the muzzle of the barrel and a blank cartridge in the breech; the barrel then has the dimensions of a service cartridge, and the marksman handles it as such. The target is of paper and the surface to be hit is a circular one, 4 inches in diameter, at a range 50 feet. On shore the range may be 100 feet and 150 feet, at targets of 10 and 20 inches diameter. The targets are mounted on large screens which catch stray bullets.

The annual allowance for sub-calibre practice is 100 rounds, of which 40 rounds are expended in individual firing and the rest in volley firing under the orders of the chiefs of the fighting groups. All the allowance must be expended.

This practice is readily carried out on shipboard.

Target practice.—The annual allowance for target practice is 100 rounds for riflemen and 36 rounds for men not armed with rifles in action. There is also an allowance of 30 blank cartridges for the riflemen and 15 blank cartridges for the rest of the crew.

Instruction firing is carried out individually at ranges of 100, 200, and 300 metres, either on shore or afloat, but preferably on shore. The entire crew performs the instruction firing, expending 36 rounds, of which 9 are expended in 40 seconds, using the magazine.

An extra allowance of 24 rounds is expended by the riflemen in individual firing at ranges of 200, 300, and 400 metres, under the same conditions.

19 rounds are expended in collective firing by the landing force, of which 6 are volleys on shore at 600 and 800 metres, 9 are in skirmishing order on shore (from the magazine), advancing from 500 to 150 metres, and ending by exhausting the magazine supply, and 4 are from boats at any range.

21 rounds, completing the hundred allowed, are expended in collective firing by the riflemen organized for battle, of which 3 are expended in squad volleys on board at 400 metres; 9 in squad volleys, using the magazine at ranges of either 200 or 300 metres; and 9 in file firing from the stations at quarters at any range, finishing by exhausting the magazine.

Targets.—The targets for use up to 500 metres are 2 metres (6 feet 7 inches) square. For use at 100, 200, and 300 metres circles are marked on the centre of the target, whose diameters are .5 metre, 1 metre, and 1.5 metres, respectively. These circles correspond to the size of an ordinary shot group for the range. At 400 metres a rectangle of 2 metres high by 1.5 metres wide is marked in the middle of the target. At 500 metres the whole target is used. At 600 metres a rectangle 2 metres high by 3 metres wide is used. A vertical and a horizontal axis are drawn on every target.

The volley firing screens are formed by joining rectangular targets to make a width of from 5 to 10 metres. Skirmish firing is at a line of silhouettes. Collective firing on shipboard and boat firing take place at targets large enough to give an appreciable percentage of hits. The target may have the shape of a boat end-on. For individual practice from the ship the target may be either a linen globe or two concentric steel discs, with planes at right angles to each other, supported at the water's edge by floats. The radii of these targets are the same as those of the circles on the shore target for corresponding ranges. Any hit on the floating target or within the circle marked on the shore-target scores one, and outside zero. The percentage of hits within the limits is the score.

The reasons for this method of scoring are given in full (in the seventh edition); but, briefly, it is because when the target is large enough to catch all the shot of a good marksman, two shot equally well aimed may strike at different distances from the center, either because the mean trajectory does not pass through the center of the target, or on account of the imperfections of the arm and ammunition independent of the marksman. The record is evidently much simplified by this method of scoring.

Fifty per cent. of hits puts a man in the first class, 20 per cent. in the second class, and less in the third class.

Rewards.—A reward of 10 centimes (2 cents) is paid for every hit; but when using the magazine it must be emptied within the prescribed time or the score is 0.

Matches take place in each squadron, for which the prizes are watches, telescopes, &c., whose number and values are decided by the Department of Marine.

Practice from tops.—In comparing the manual now in force with that of its predecessor, we find that the latter required target practice from the tops, which does not now seem to be the case.

Judging distance.—The latter also required judging-distance exercises both on shore and afloat from the deck and from the tops. The present manual requires such practice on shore only, the method of instruction being similar to that of the Army. The exercise on shipboard is carried out by sending boats to manœuvre according to signal, while the men on board, divided into groups of ten to twelve, estimate the ranges, which are measured by sextant at the same time.

School of musketry.—The school of musketry on board has for its object to teach the men armed with rifles to occupy with the greatest rapidity the places where they can best direct their fire on the target assigned to them.

Rapidity in these movements is indispensable with the present speed of ships and steam launches, and to obtain it, every post on the poop, forecastle, and in the gangways, tops, and boats from which sharpshooters can conveniently fire must be minutely designated. Each one of these posts will be plainly marked with the number of the men it can accommodate, and the necessary arrangements will be made to enable men to fire readily. Besides, posts on the deck will be selected from which to fire volleys.

Then follow directions for exercising the men in manœuvring about the decks.

Remarks.—The French system of naval musketry instruction is based upon that of the army, and the system of training is assimilated thereto as far as possible.

The importance of volley and collective firing is insisted upon, and great attention is required for the exercises necessary to develop such skill, both in boats and on shipboard.

Individual practice takes place only at ranges of 400 metres or less. Collective firing is practiced at all ranges up to 800 metres.

The bounty for each hit at target practice seems an excellent way of encouraging skill.

GENERAL CONCLUSIONS IN REGARD TO MUSKETRY INSTRUCTION.

A system must be adopted which shall be definite in every particular and it must be strictly enforced.

On this point the experience of the U. S. Army, as narrated by General J. C. Tidball, U. S. A., Ordnance Note 237, is very clear. He says:

> Notwithstanding that the Army had now [after 1859] become armed entirely with an efficient rifle, and that a good system of target practice was available for its guidance, but little attention was given to it, and, consequently, but little progress made in instructing the troops in the use of the improved arm. * * * There still appeared to be something lacking, some force wanting to give vitality to the desired movement. The trouble seems to have been that the Army was expected to take up the subject of rifle practice spontaneously and without specific orders as to allowance of ammunition, time of practice, and method of making systematic reports.

Before proceeding to consider the method of training, that of sighting the rifle demands thought as a matter intimately connected with training.

The Germans find that with their service rifle the trajectory is so flat that they only need two sights under 400 metres (440 yards). With the flatter trajectories and greater accuracy of the most recent small-arms, the limiting range under which only two sights need be used would be increased to 500 or 550 metres (550 or 605 yards).

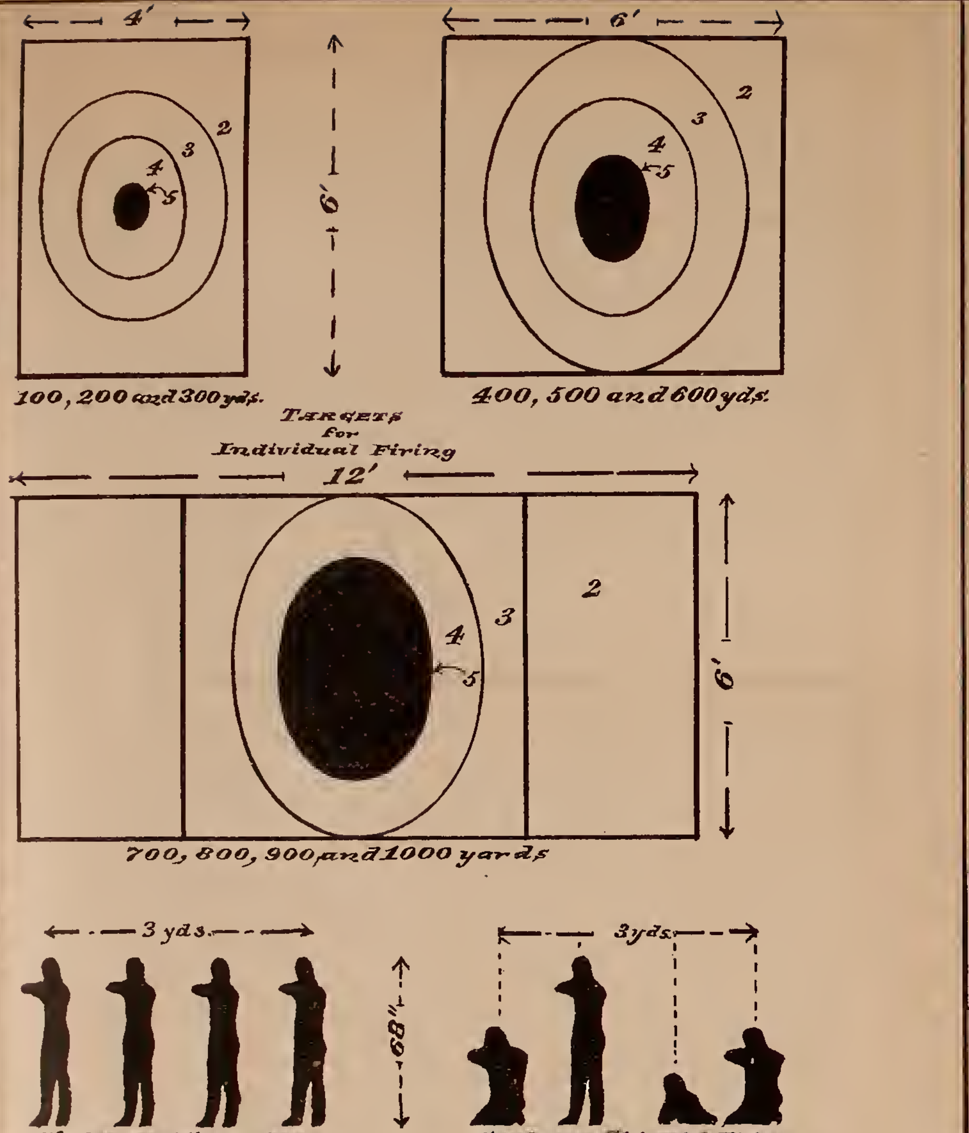
This is shown in Fig. 13, plate 2. The trajectories in full lines represent those corresponding to the three lowest sights of the German rifle; namely, those of 270, 350, and 400 metres. It will be noticed that when aim is taken at the foot of the target, using the 400-metre sight, the trajectory nowhere rises to the height of a standing man, so that if the enemy advances upright, the sight need not be altered after the 400-metre range has been passed. Similarly, the 350 and 270-metre sights are effective at all less ranges against kneeling and lying men respectively. With the experimental rifle whose trajectories are shown in the same figure, the sights effective at all less ranges against standing, kneeling, and lying men are increased to 500, 400, and 300 metres, respectively.

The small calibre experimental rifle has a much greater accuracy, as shown in Fig. 13 by the sizes of the circles containing 50 per cent. of the bullets fired at varying ranges with each of the two rifles.

The advantages gained by the use of only three sights for all short ranges are evident, and are even more marked in naval warfare than on shore, on account of the greater rapidity with which ranges change. The corresponding disadvantage of loss of accuracy at exactly known ranges is a very trifling objection for military or naval use, and may be greatly lessened by proper instruction.

In training, the necessity for careful and long-continued preliminary drills, and for practice with reduced charges or sub-calibre target practice, cannot be too strongly impressed. There are a number of systems of sub-calibre practice whose results probably do not greatly vary. Such practice is admirably adopted for ship's use, and should be carried out both individually and collectively.

Ball target practice should succeed sub-calibre practice. It is the general custom in all services, except the U. S. Army and the British



100, 200 and 300 yds.

400, 500 and 600 yds.

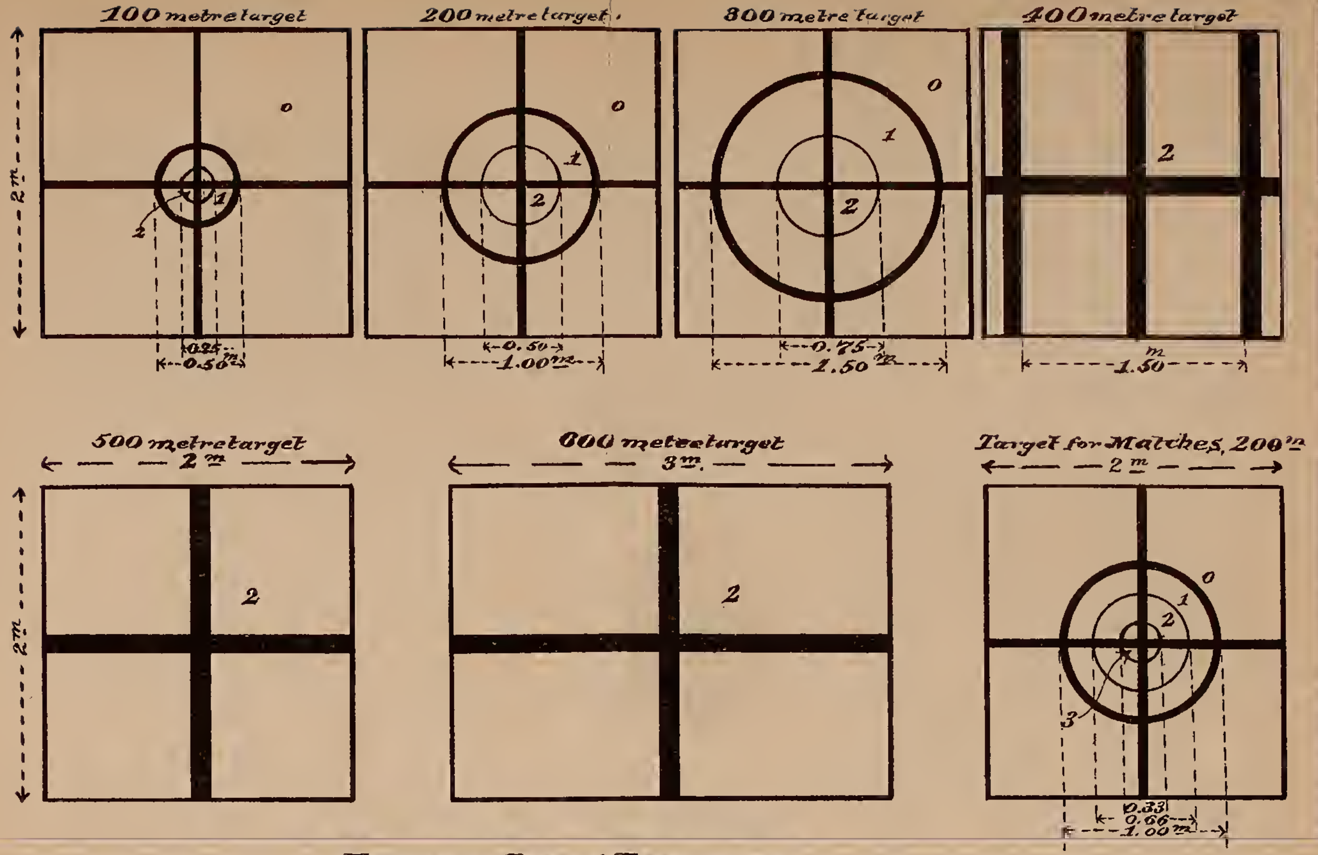
Targets for Individual Firing

700, 800, 900 and 1000 yards

Volley and File Firing Target

Company Skirmish Firing Target

U. S. ARMY TARGETS



100 metre target

200 metre target

300 metre target

400 metre target

500 metre target

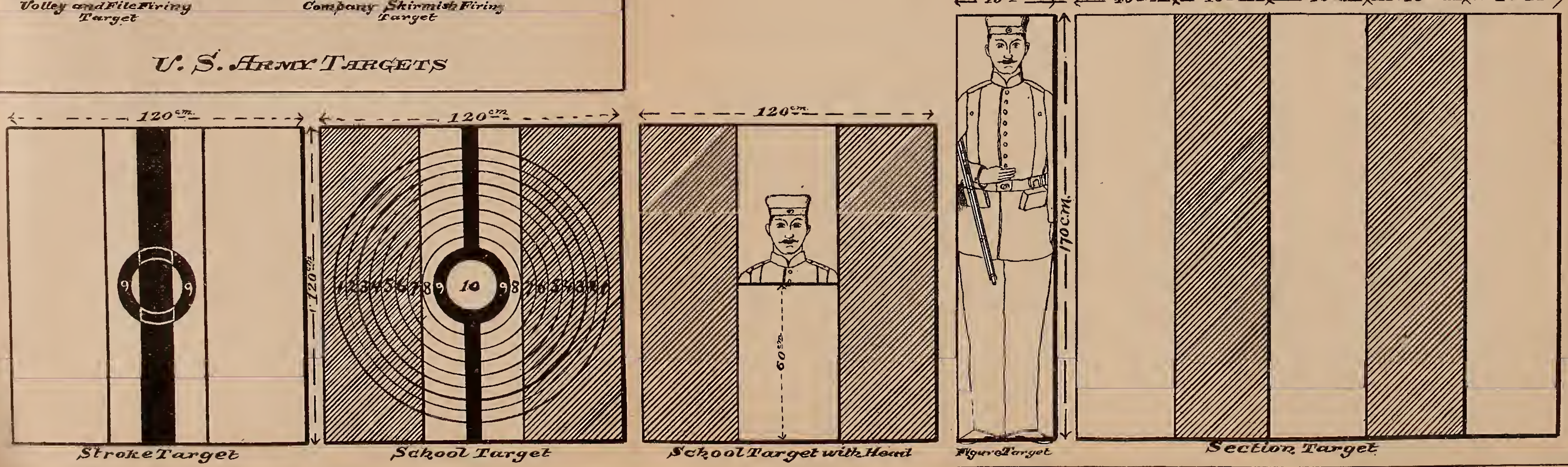
600 metre target

Target for Matches, 200m

FRENCH ARMY TARGETS

Note—Figures on face of target indicate values of hits

GERMAN ARMY TARGETS



Stroke Target

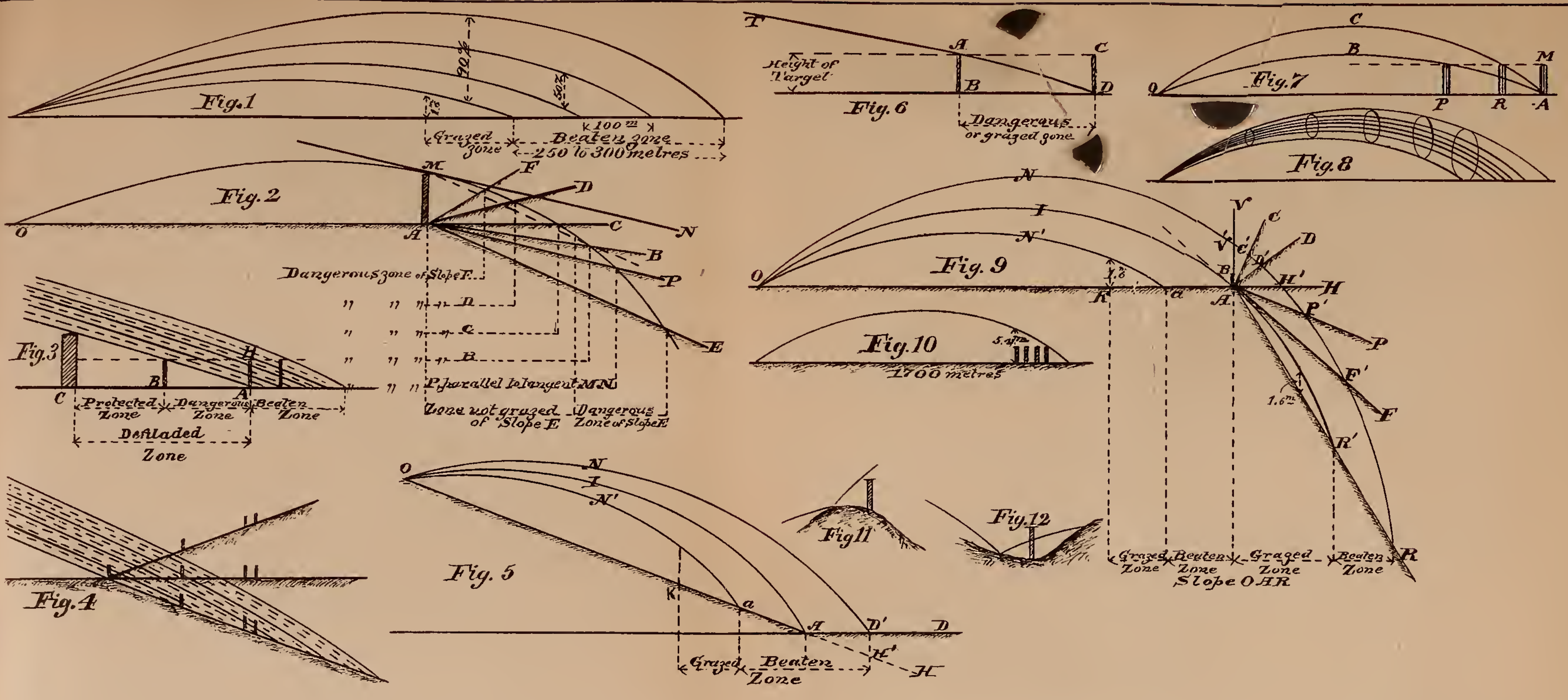
School Target

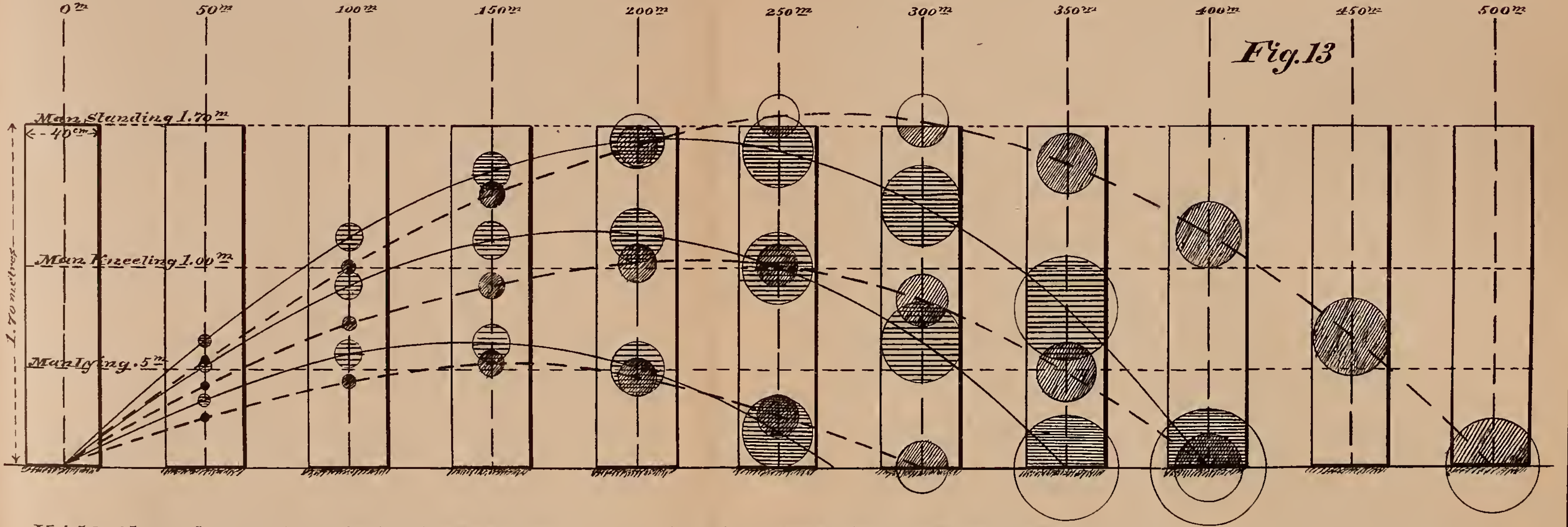
School Target with Head

Figure Target

Section Target

PLATE 2





Height of trajectories above the fixed lines of sight. Points of sight, the foot of the targets.

——— Trajectories of German service rifle using fixed and flap sights and 400 metre sight, calibre 11m/m (.433), initial velocity 440m (1443 ft.)

– – – " " Hebler experimental rifle for 300, 400 and 500 metre ranges, Calibre 7.53m/m (.296), initial velocity 600m (1968 ft.)

▤ Spaces catching 50% of shots from German Service rifle.

▨ " " " " " " Hebler Experimental rifle.

EFFECTS OF FIRE ON SLOPING GROUND
Elevation, 1000 metres

PLATE 3

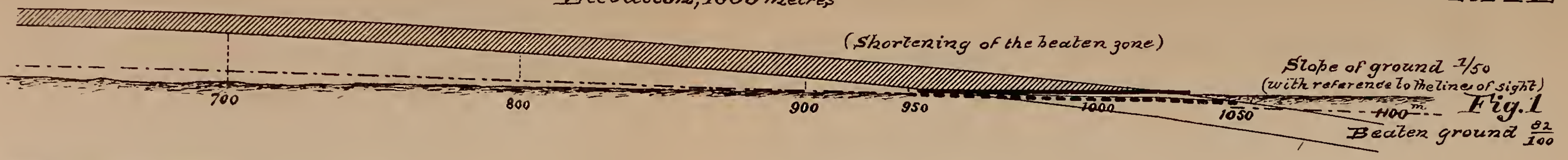

(Shortening of the beaten zone)
Slope of ground 1/50
(with reference to the line of sight)
700
800
900
950
1000
1050
1100m.
Beaten ground 82/100

Fig. 1

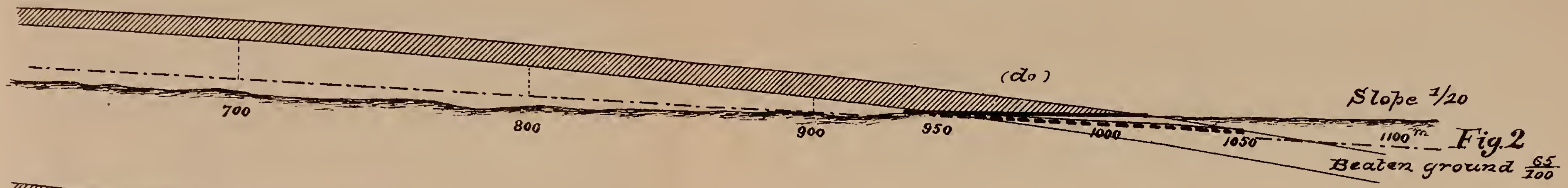


Fig. 2

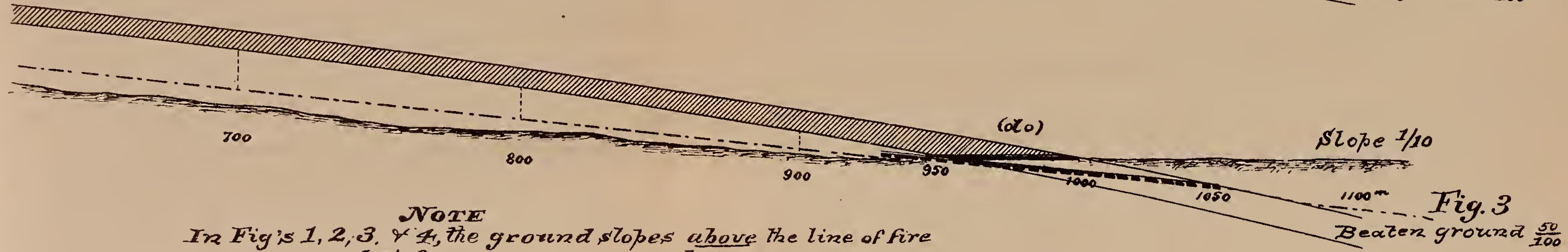


Fig. 3

NOTE

In Fig's 1, 2, 3, & 4, the ground slopes above the line of fire
" " 5 & 6, " " " below " " " "

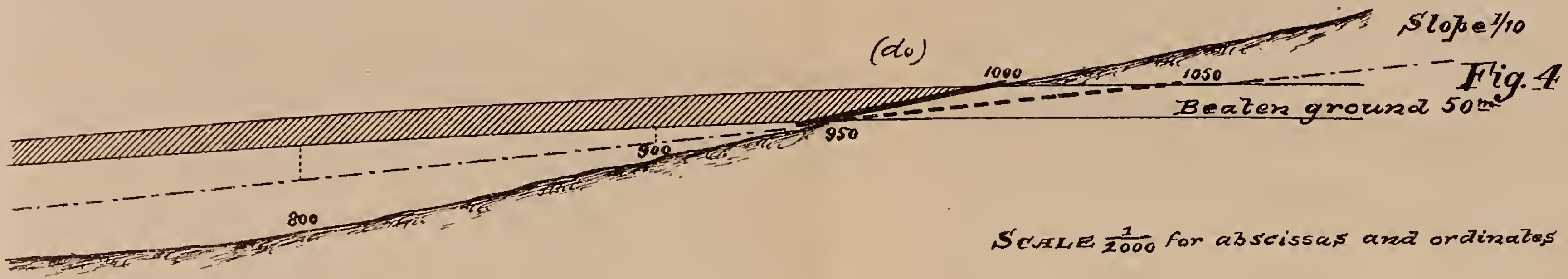


Fig. 4

SCALE 1/2000 for abscissas and ordinates

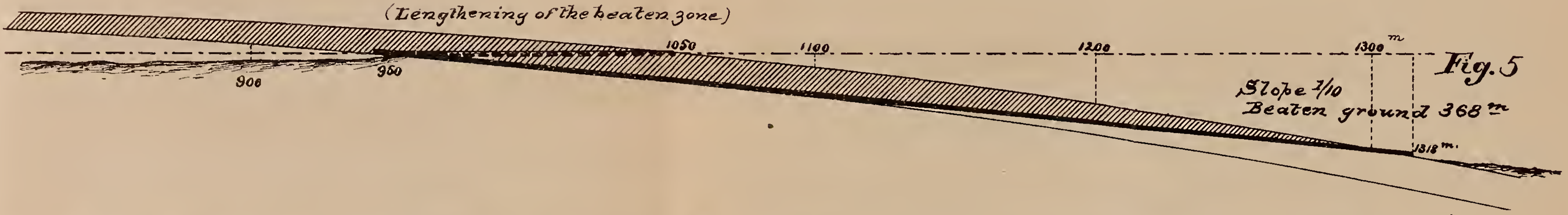


Fig. 5

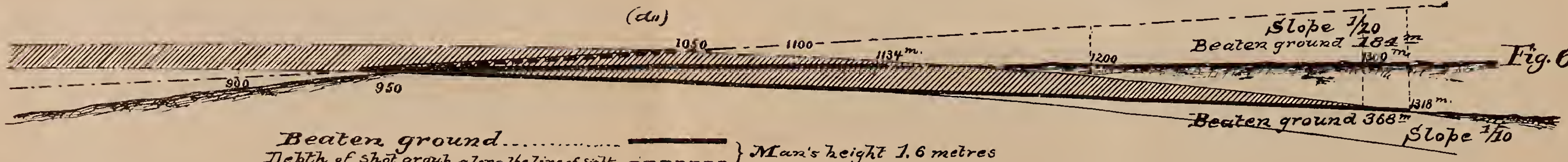


Fig. 6

Beaten ground .... ▬▬ }
Depth of shot group along the line of sight ---- } Man's height 1.6 metres

services, to limit individual practice to the short ranges (*i. e.*, under 450 yards). Collective fire should be practiced up to 900 or 1,000 yards. In the French navy, whose training has always been remarkable for its perfection of detail, very great weight is laid upon the development of the methods of collective firing in use by the continental armies, upon assuring the control of petty-officers over the fire of their squads, and upon exercising the former therein and developing their judgment in regard to firing. This is much aided by having men always instructed and exercised by the petty-officers who command them in battle. Practice from boats and tops, as well as from the decks and on shore, must not be neglected.

Skill in judging distance is of great importance, and judging-distance drills should be carried out from boats, and the decks and tops of ships as well as on shore.

A system of rewards for good shooting is adopted by all the services whose musketry instructions have been examined in this article, the U. S. Navy alone excepted. In Great Britain there is also a system of rewards for proficiency in judging distance.

Rewards are granted according to three systems:

(1) Honorary rewards in the shape of medals or badges to the best marksmen in an organization, or to those reaching certain standards of skill in shooting.

(2) A series of money prizes of fixed amounts to the best marksmen in an organization, or to all of those reaching a certain standard.

(3) A fixed reward in money for each hit or point made by each man.

A combination of the first and third systems would seem most efficient and just; and as skill in judging distance is scarcely less important than skill in shooting for the men, and is even more important for officers and petty-officers, rewards should be given for proficiency in this exercise as well.

In regard to the employment of small-arm fire in naval warfare, it seems evident that machine and R. F. guns will replace small arms to a great degree, and that a body of riflemen, or even single sharpshooters, about the decks are not only greatly exposed without commensurate results, but, as the French think, the noise and smoke of the small-arm fire may seriously interfere with the command of the ship; that is, with the transmission of orders and uninterrupted view of the horizon. The reserve riflemen called on deck when they are needed will probably prove amply sufficient as deck riflemen.

In the tops, however, the small-arm men are most favorably situated to deliver an effective fire and to obtain shelter; but they must be constantly exercised there at other times than at general quarters, which exercise, as a French writer says, teaches the men very little.

Small-arm fire should not be permitted at ranges over 900 yards, and beyond 450 yards it should be under the strictest control, and no individual firing should be permitted.

VIII.

[The following article, read before the Institute of Naval Architects by Mr. J. H. Biles, of the firm of J. & G. Thomson, Glasgow, in April last, presents the question of the relative values of belted and internal protection of vessels in such a skillful and graphic manner that it is here republished for the benefit of naval officers and architects and others interested in following the developments of naval design. Taken in connection with the discussion upon it (as published in Engineering, April 15, 1887), it must be considered as most valuable and instructive.—Ed.]

BELTED AND INTERNAL ARMOR.

COMPARATIVE EFFECTS OF BELTED AND INTERNAL PROTECTION UPON THE OTHER ELEMENTS OF DESIGN OF A CRUISER.

By Mr. J. H. Biles.

The question of the best method of protecting cruisers is a subject which has caused a considerable amount of discussion. The widespread interest in naval circles which this question naturally arouses must be my excuse for venturing to bring this subject before this Institution.

The belted type of protection may be described as a belt or strip of vertical armor, forming the side of the ship in the vicinity of the water line, and surmounted by a flat deck of about one-fifth of the thickness of the belt, forming with the belt a shield over the machinery and magazines of a ship.

The internal type of protection is usually represented by a steel deck extending from side to side of the ship, but, instead of ending with a belt of armor, it is sloped down at the side, joining the outside bottom at approximately the same point that the bottom of the armor does. The sloping part of the deck at the side of the ship is usually thicker than at the middle.

If the thickness of the internal deck be properly chosen, it is evident that the protection of the machinery and magazines from the effects of shot and shell fire may be made equal to that of the belted type. But the essential difference between these two types lies in the fact that, in the vicinity of the water line, for a small height, the belted ship offers resistance to penetration, which would be followed by the admission of water, while the protected ship practically offers none. Assuming that it is desirable to have a belt, which some have very emphatically stated to be of vital importance, it is desirable to investigate the effect that the adoption of such a method of protection has upon the speed, cost, and other qualities of a ship, which, but for the adoption of this belt, would have had an equally good protection to her machinery and magazines in the form of an internal curved deck.

To make a definite comparison I have selected the latest type of belted cruiser which the English Admiralty have built, viz, the Aurora type. The particulars of these vessels have been already published, but, for purposes of reference, they are given here:

Length between perpendiculars	feet	300
Breadth, molded	do	56
Depth, molded at side	do	37
Draught, mean	do	21
Displacement	tons	5,000
Thickness of belt armor	feet	$\frac{5}{6}$
Thickness of backing	do	$\frac{1}{2}$
Height of belt above L. W. L	do	$1\frac{1}{2}$
Depth of belt below L. W. L	do	4
Length of belt, about	do	200
Thickness of deck above belt	do	$\frac{1}{6}$

NOTE.—Before and abaft the belt, the deck becomes an internal protective deck, and slopes down at the sides. The thickness of the sloping part is 3 inches, that of the flat, 2 inches.

Armament—Two 9.2-inch B. L. guns, one forward and one aft; ten 6-inch B. L., guns; and a number of small guns.

Coals, normal supply	tons	*500
Coals, full suppy	do	*1,000
Metacentric height in intact condition	feet	*2
Speed	knots	*$18\frac{1}{2}$
Indicated horse-power		8,500
Weights, approximate—		
Provisions, stores, outfit, armament, and auxiliary machinery	tons	*660
Machinery and engineers' stores	do	*830
Protection	do	*880
Hull and conning tower	do	*2,130
Coals	do	*500
	Tons	*5,000

Starting upon the basis of these figures, I have estimated the corresponding particulars for a vessel of the protective deck type, which fulfills, as nearly as possible, the same essential conditions as the belted cruiser, except in the matter of side protection. The comparative assumptions upon which this design is based are:

(1) Length and draught of water to be the same.

(2) Armament to be the same, carried at the same height above water.

---

* Estimated by the author.

(3) Protection to be the same thickness on the flat as the deck of the belted cruiser. The sloped part to be at an angle of 28° and its, thickness, measured horizontally, to be the same, viz, 10 inches.

(4) Crew to be the same.

(5) Metacentric height, in intact condition, to be the same, viz, 2 feet.

(6) Speed to be the same.

(7) The capacity of coal-bunker above the protective deck is the same.

(8) Forms to be similar.

Upon these assumptions, the principal elements of the design will be as follows:

Design 2:

Length between perpendiculars	feet	300
Breadth, molded	do	53¾
Depth	do	34¼
Draught, mean	do	21
Displacement	tons	4,790
Thickness of deck on slope	inches	4.69
Thickness of deck on flat	do	2.0
Height above W. L., at centre	feet	0
Depth below W. L., at side	do	6

NOTE.—Before and abaft the distance that the belt extends in the belted cruiser, the decks are assumed to be of the same character and thickness in the two ships.

Armament, same as belted ship. Coals, normal supply=500 tons; full supply=1,000 tons. Speed=18½ knots. Indicated horse-power=8,250.

Weights, approximate—

Provisions, stores, outfit, armament, and auxiliary machinery	tons	660
Machinery and engineers' stores	do	805
Protection	do	675
Hull and conning tower	do	2,050
Coals	do	500
		4,690
Margin of displacement=100	do	4,790

Thus, on the above-named assumptions, we have 100 tons more available displacement.

The debatable points of the above assumptions are Nos. 3 and 7. With respect to 3, it may be objected that no credit is given to the plating behind armor and the backing, nor to the fact that the outside armor is steel-faced; but we have to set against these the fact that a plunging shot might strike the 2-inch deck in the belted cruiser, in the part which is occupied by the sloped deck in the protective deck cruiser, and penetrate the former when it would fail to penetrate the 4¾ inch deck of the latter; also, the coal protection in the latter is likely to be greater. Taking these facts into consideration, the fairest comparison for protection of machinery and magazines seems to me to be as in assumption 3. With reference to the bunker capacity, the assumption 7 is based on the consideration that the amount of coal which can be carried is ultimately limited, not by the space available, but by the weight which the commander considers it desirable to carry for the special purpose of the voyage he is about to undertake; and also by the consideration that the best arrangement for fighting is that which gives the greatest proportionate amount of coal above the armored deck, for a given initial metacentric height. In other words, the lower bunkers should have as little coal as possible, and, consequently, the total space occupied by coal is independent of the difference in size of the lower bunkers in the two ships.

From the foregoing list of weights it has been shown that 100 tons of displacement is to spare, in favor of the internally protected type. This weight is capable of either—

1. Adding 40 per cent. to the thickness of the flat part of the armored deck amidships;
2. Or adding about a six-tenth of a knot to the speed of the ship;
3. Or adding one 9.2-inch gun and two 6-inch guns to the armament.

But it may perhaps be claimed that, in comparison of the two types, the condition of equal draught of water should be set aside in favor of that of equal displacements. This would make available a very much larger amount of displacement for additions of the nature of the above. Dealing only with the second one—increase of speed—and adhering to all the other assumptions, excepting the equality of draught, which is replaced by equality of displacement, we are led to the following as the elements of the design:

Design 3:

Length between perpendiculars	feet	300
Breadth, molded	do	53
Depth	do	34¼
Draught, mean	do	21⅚
Displacement	tons	5,000
Thickness of deck on slope	inches	4.69
Thickness of deck on flat	do	2.0
Height below W. L. at centre	feet	⅚
Height below W. L. at side	do	6⅚

NOTE.—Deck at ends same as before.

Armament same as belted cruiser. Coals, normal supply=500 tons; full supply=1,000 tons. Speed 20 knots. Indicated horse-power=11,600.

Approximate weights—

Provisions, stores, outfit, armament, and auxiliary machinery	tons	670
Machinery and engineers' stores	do	1,125
Protection	do	670
Hull and conning tower	do	2,035
Coal	do	500
		5,000

Thus an increase of speed of 1½ knots may be obtained in the internally protected type over the belted cruiser, on the above assumptions, at the same displacement. In the design 3, if the protection be added to instead of the power of machinery being increased, about 44 per cent. may be added to the thickness of the whole of the deck plating.

The question of relative cost of the two types is of importance. The Aurora's estimated cost is for hull £215,550, and for machinery £64,000, or £279,550. The cost of hull is made up of what may be called the armored and the unarmored part. The former consists of the conning tower and protected tubes (ammunition hoists), which in all the comparisons in this paper are assumed to be the same—the armored deck and the armor and backing on the side. I think the unarmored part of the hull will cost £169,500, the conning tower, protected tubes, &c., which are the same in all the cases, will cost £6,000, and the armored deck and side will cost £40,000. The cost of hull is £82.7 per ton, and this rate may be assumed, without great error, for the hulls of the other designs. From this basis the cost of No. 2 design is estimated to be for hull £162,919; for conning tower, &c., £6,000, and for protective deck £10,125, or a total of £179,044. The machinery in this case is £62,060. Total cost of vessel is £241,104, against £279,500 for the belted ship. It is, therefore, evident that, as a question of first cost, the internally protected ship is £38,396 cheaper. In other words, a vessel of much greater size and increased powers of offense and defense can be built for the same money of the internally protected type than of the belted type. I have determined the elements of the design of a vessel of about the same first cost as the Aurora, upon the same data as above, and they are shown in the following table, design 4, the other three designs being placed with this one for facility of comparison:

	No. 1.	No. 2.	No. 3.	No. 4.
Length .... feet..	300	300	300	316
Breadth .... do...	56	53¾	53¼	56
Depth .... do...	37	34¼	34¼	37½
Draught (mean) .... do...	21	21	21	23
Displacement .... tons..	5,000	4,790	5,000	5,800
Thickness of belt, or deck on slope .... inches..	10	4.69	4.69	5.63
Thickness of backing .... do...	6	....	....	....
Top of belt or deck above or below water	Above 1½ ft.	....	Below ⅝ ft.	....
Bottom of belt or deck below water .... feet..	4½	6	6⅝	6
Length of belt, or deck sloped .... do...	200	200	200	230
Thickness of deck on flat .... inches..	2	2	2	3
Armament:				
9.2-inch guns .... number..	2	2	2	4
6-inch guns .... do...	10	10	10	10
Coals (normal) .... tons..	500	500	500	600
Coals (full) .... do...	1,000	1,000	1,000	1,200
Speed .... knots..	18½	18½*	20.0	19½
Indicated horse-power	8,500	8,250*	11,600	11,500
Metacentric height in load condition .... feet..	2.0	2.0	2.0	2.0
Weights:				
Provisions, outfit, armament, &c. .... tons..	660	660	670	772
Machinery and engineers' stores .... do...	830	805	1,125	1,118
Protection .... do...	880	675	670	1,000
Hull and conning tower .... do...	2,130	2,050	2,035	2,160
Coal .... do...	500	500	500	750
	5,000	4,690*	5,000	5,800

---

* If the 100 tons surplus displacement be used for machinery, speed will be 19.1 knots.

Fig. 1.

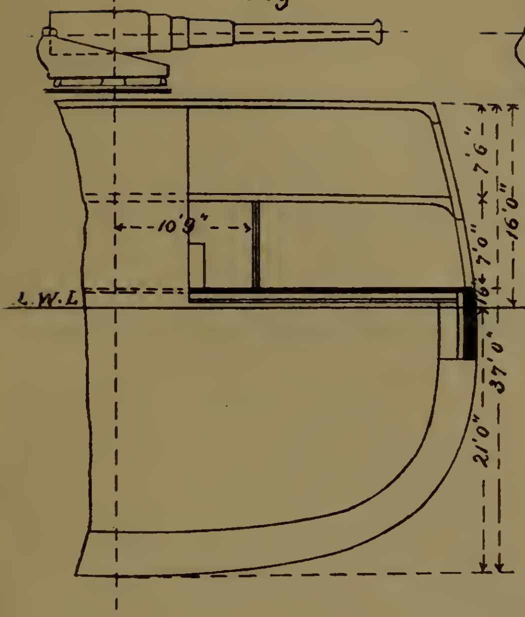


Fig. 2.

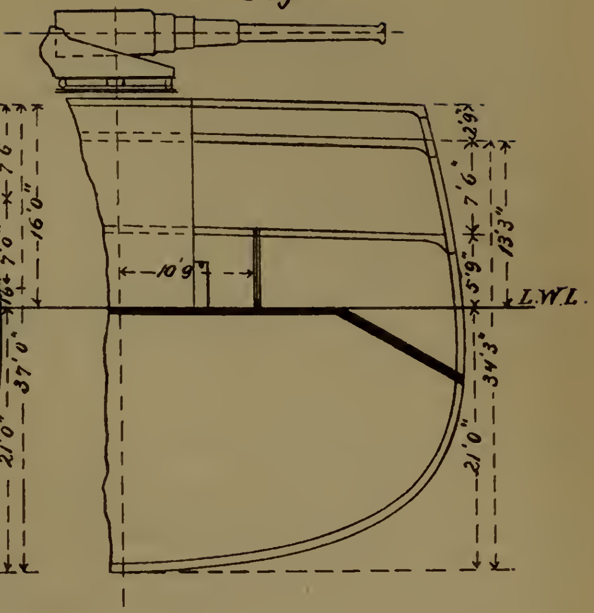


Fig. 3.

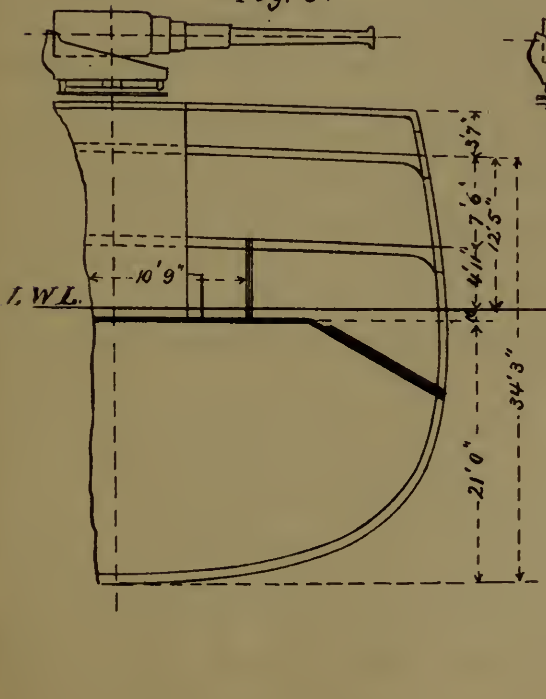
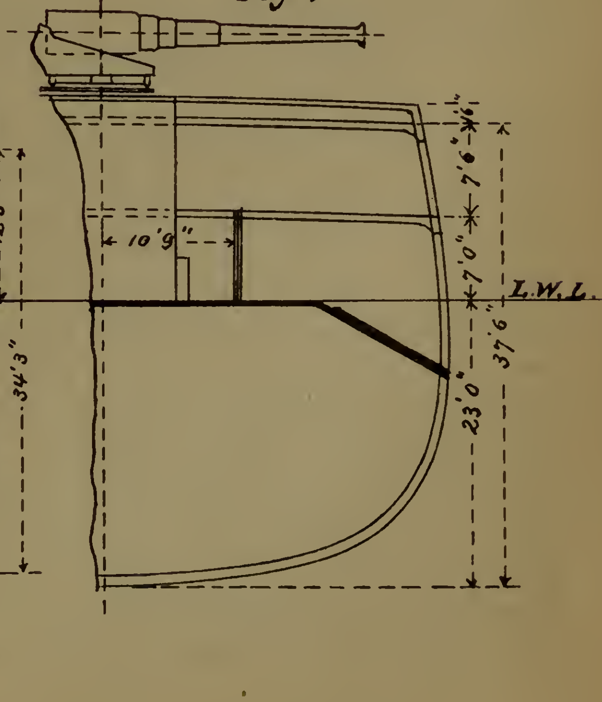


Fig. 4.



Design No. 4 :

Cost of hull	£172,000
Cost of conning tower, &c	6,000
Cost of deck protection	15,000
Cost of machinery	86,600
	£279,600

From the above, it will be seen that for about the same cost a vessel of the internally protected type can be built with 20 per cent. more protection on the slope, 50 per cent. more on the flat, two more guns of the heaviest calibre, 50 per cent. more coal, and a knot more speed. The belted ship has the advantage of the reduced length and draught, but this can be also had in the internally protected type, as in the smaller size, with the additional advantage of a greatly reduced cost.

We are now naturally led to ask the questions :

1. Is the adoption of the belt worth the extra money paid for it, with its accompanying sacrifices ?

2. If the money is to be spent, is the belt worth the sacrifice of speed, protection, and armament which is entailed in its adoption ?

The protection of the machinery and magazines from shot and shell fire is not very different, I venture to think, in the two cases. The only other question is that of protecting the buoyancy and stability by armor; but it is extremely difficult to see how a narrow strip of armor projecting, on an average, 1½ feet out of the water, and 4 feet under it, can be said to be likely to help to exclude water from a ship, in which the side, both above and below these points, will hardly keep a rifle bullet out. The sea is not so respectful to a naval architect's load-line as to make its surface conform to it at all times; and it is difficult to understand how any naval officer would agree to sacrifice anything in order to have the assurance that his ship's side might not have a hole in it at the average still water load-line, but was liable to have one that a horse and cart could drive through at 1½ feet above that line.

The question of the effect upon the stability of the two types by penetration of the unarmored side, immediately above the armored protection, may be seen by reference to Figs. 5 and 6 (not given). The metacentric diagram in each of the four cases discussed is given. It is assumed that the normal amount of coal is on board, that the reduction of weights of stores, &c., due to having been at sea for some time, is compensated for by water ballast. It is also assumed the compartments shown in Fig. 6 (end compartments and middle compartments for 50 feet of length) are damaged, and that, in order to keep the ship upright, the corresponding compartments on both sides are in communication with the sea. It is also assumed that the motion of the sea and the ship is sufficient to cause the water to enter freely the holes made in the side. In these conditions, and on these assumptions, it will be readily seen how much remaining stability there is in each case, The following table shows clearly the amount of metacentric height, with the same amount of riddling in each case:

	No. 1.	No. 2.	No. 3.	No. 4.
Load condition, intact—A .... feet..	2.0	2.0	2.0	2.0
Load condition, riddled—B .... do...	0.44	0.41	0.55	0.86
Deep load condition, intact—C .... do ..	1.9	2.0	2.0	2.0
Deep load condition, riddled—D .... do...	0.37	0.48	0.8	1.05

The amount of metacentric height remaining, after riddling, is a proper measure of the protection to the stability afforded by each method of protection, and it will be seen that the percentage differences are very considerable.

I have ventured to put these facts before the Institution in the form in which they have presented themselves to me, but they do not, by any means, exhaust the question, and I hope that they may lead to the eliciting of many other facts in the discussion of this interesting question.

DISCUSSION.

Admiral de Horsey opened the discussion by stating that he considered the contribution of Mr. Biles the most important that had ever been heard in that theatre. In criticising the statements put forward he would confine his remarks to the designs illustrated by Figures 1 and 3. The first of these, it will be seen by reference to accompanying plate, is that of a belted cruiser of the Aurora type, whilst the other is an imaginary vessel of the protective deck type. In considering the relative merits of the two ships it would be necessary to suppose them to be struck by a projectile at their worst points. In No. 1 that would imply a blow 18 inches above the water-line, or immediately above the belt. In design No. 3 the weak spot would be exactly at the water-line. The speaker desired it to be understood that he was leaving out the question of unarmored ends, a subject he understood to be not before the meeting. He would suppose a hole big enough for a horse and cart to go through. That would be a big hole, no doubt, but it would be fair assumption. In such a case No. 3 would have a compartment filled of sufficient size to cause the vessel to turn over and go to the bottom. In the belted cruiser the shot would make a hole of a similar size, and water would flow in; but the difference in this case would be that the water would be admitted above the water-line, and it would flow out again. Therefore, in No. 1 the vessel would be so far safe, unless guns were brought to bear upon her that could pierce the armor belt. In No. 3 again the disposition of coal was such as to prevent the side being reached so as to stop a leak in case of penetration. The question of cost had been dwelt upon, but it would be no satisfaction to the country to be told when No. 3 had been sent to the bottom by No. 1 that she was £30,000 cheaper.

Sir John Hay followed his brother officer. He remarked that Mr. Biles had asked whether the adoption of the belt was worth the price that had to be paid for it. The speaker objected to the question being stated in this manner. He would put it in this way: "Would an officer of a ship make these sacrifices to prevent a hole being made in his vessel's side at the still water load-line?" Now, it was a bad thing to have a hole at the still water load-line, and therefore he thought many sacrifices should be made to prevent it. Then, as to the vessel rolling—which would destroy the still water load-line, and give a considerable vertical height on the ship's side as load-line—the speaker pointed out that many engagements would doubtless be fought in smooth water, notably in cases of vessels engaging batteries. Therefore he was of opinion that the belt should be at the water-line. But the speaker further refused to be fettered by the propositions of the author. When the Admiralty were building vessels for the Royal Navy to protect Her Majesty's kingdom, there should be no question of size, as dominated by the question of cost, enter the heads of designers. If the five celebrated Italian ships were opposed to us in the Mediterranean, the question would be, how should we catch, and having caught, how should we engage them? We want an Intelligence Department to tell us that. They should find out what our friends are doing, and then, whenever we hear a ship of a certain kind is being built, we should at once set to work and produce one better to meet it, if ever the need arose. If we want to be supreme on the sea, this is what must be done. The speaker expressed his disbelief in coal protection, for if the coal was depended upon to protect the ship, it was evident it could not be burnt.

Captain Fitzgerald, R. N., said that the belt of the Aurora was 18 inches above L. W. L. and 4 feet below. He wished to point out that Sir Nathaniel Barnaby had said that the belt would be only 4 inches above the water line, a statement which Sir Nathaniel met with an emphatic "No." But with 900 tons of coal on board it would be so; a proposition to which the late Director of naval construction assented. Then, continued the speaker, according to the regulations of the present Board the ship would go to sea with only 4 inches of armor above water. To select such a vessel as a type of a belted cruiser on which to form a comparison was a travesty, a burlesque. As to plunging fire, it was more likely to go through a sloping than a horizontal deck. In speaking of the distribution of armor he had no wish to go beyond the limit of the paper, but it was absolutely necessary to consider the matter as a whole. The armor was not intended to keep out the ram or torpedo, and he would point out that once the torpedo was launched at 600 yards nothing the ship could do in the way of manœuvring to avoid it would be likely to be of much avail. But the whole question was one of chances, and here he would exclaim against the way in which facts were misread. Armor plates were put up and fired at so that the shot struck at right angles. This was the most favorable condition for the shot, and plates were accordingly condemned. In actual war, however, ships were not going to lay alongside each other as in old days and then blaze away. The naval engagements of the future would consist, the speaker considered, of a series of manœuvres in which at least 95 per cent. of the projectiles that hit would strike at greater or less angles, and would not get through the armor. Captain Fitzgerald, however, looked on the quick-firing gun as the most deadly weapon—more so than the torpedo. The chances of a shot striking an enemy were as a thousand to one in favor of the quick-firing guns compared to the projectiles of the heavy armament. The big gun business, the speaker considered, had been overdone. Success in action would not be a question of a horse and cart hole, although there was, of course, the possibility that an enemy might be polished off by one lucky shot, but this was a thing that they would have to take their chance of. For this reason he would prefer the belt. Captain Fitzgerald would not accept the belt shown in the diagram. He would have more of the belt above than below water, as the chances of a blow above were far greater, for there was the water to deflect the shot from below the water line. It was customary, the speaker pointed out, for naval architects to point out how difficult it has always been to sink vessels by firing at them, and instanced the naval engagements of old times, when the sides of ships would be riddled and yet the ships would not sink. This was with wooden ships. The effect of a shot passing through the thick wooden sides of vessels was very different to that of passing through the side of an iron ship. In the former case the splinters would swell so much from the wet being admitted, that a shot might go clean through and not leave a hole larger than one could see through. As to the armored deck the speaker did not believe in it. If the ship got pierced and water was admitted above the deck, the cry would be, not how to keep it there, where it would destroy the vessel's stability, but how to let it run below to the pump suctions. He considered the armored deck a waste of weight.

Captain Colomb followed his brother officer. Most of what he would have said had been already said by those who had preceded him, and he was glad to find naval opinion run as it did. The paper asked if it was worth while to give up certain advantages to get the protection of the belt. Soon after armor was introduced ships carried only two or four heavy guns, but, chiefly through the influence of naval opinion, smaller guns are now coming in. The chances of hitting at the water line are not so great as are generally considered. With rifled ordnance the shot will *ricochet*, rising high over the ship. This was a noticeable effect with projectiles from rifled guns. Half a dozen actions might be fought and not a single ship be hit by heavy projectiles at the water line. Why then, it might be asked, should the belt be deemed necessary? The speaker had never been so clear on the point as he had been since he saw an experiment made to prove the effect of perforating a ship above the water line when in a seaway. A model had been constructed representing a part of a ship, such as the No. 1 design, and a hole had been made representing a shot hole above the water line. The water was agitated to represent waves, and the water then flowed in, covering the armor deck, so that the ship gradually heeled over, capsized, and sank. By this experiment it was shown that more water would be thrown in by the waves than would flow out again, so that although the hole might be above the water line the ship would gather water. The speaker was very much impressed by what he saw, but on thinking the matter over he remembered that in former times he was accustomed to see tons of water on a ship's deck without feeling any concern. This was because those ships had freeing scuttles, and it then struck him that the reason the model sank was for the want of freeing scuttles. In the case of design No. 3 freeing scuttles would be useless because the deck was below the water line, but in No. 1 design the vessel would be safe so long as the armor belt remained intact. He would add that the whole belief of the navy was in design No. 1, but if the naval architects were right and the naval officers wrong, the former should prove their case by arguments the latter would understand, and not take refuge in strings of tables and technicalities that were only understood by themselves. In this way they would gain the confidence of the navy.

Sir Nathaniel Barnaby, who rose next, said he found himself in a very peculiar position. Mr. Biles had attacked the design of the vessel of the Undaunted (Aurora) class, as represented by design No. 1, because they had too much armor, and he was responsible for these ships. It was, however, a pregnant fact that since the speaker had left the Admiralty in 1885, not a single ship with side armor had been commenced for any foreign Government; a statement which drew from Captain Fitzgerald the remark that it was a good job too. That, said Sir Nathaniel, may be, but it was necessary to look at the matter from different points of view. The speaker knew the foreign designers, and knew them to be very able men, and no sensible man could do otherwise than respect their opinions and conclusions. But, continued the speaker, it must not be supposed that these foreign ships are like those which Mr. Biles had shown on the walls. The armor deck is sometimes above water, but when below there is a provision made for excluding water in the shape of cork, coal, stores, &c. It had been said that cost ought not to enter into the question, but that could not be maintained. Mr. Biles, like other ship designers, had to take as the foundation for his design how he could give the best value for money. He represented a large commercial establishment, and unless he kept this view constantly before him, he might as well shut up the yard. Referring to the particular designs shown, the speaker thought that there should be a larger metacentric height for ships with an under-water deck, such as those illustrated. Captain Fitzgerald had stated that constructors assumed that iron ships would be as difficult to sink as wooden ones. This was not so, and in order to meet the case the armored deck was carried right fore and aft from end to end. Captain Fitzgerald preferred more of the armor belt above water, but he appeared to forget that if a shot penetrated below the water line it would be fatal, whilst it might enter above with comparatively little effect. His principle in designing ships had been to take care that the enemy could not sink the vessel by a single blow. As to the destruction of a vessel by small quick-firing guns, that would be a question of time, and there would be quick-firing guns on both sides, so that each ship could defend itself by attacking its opponent with these weapons. He considered that a ship which could be sunk by another of the same size by a single blow must be badly designed. In conclusion the speaker pointed out that the ships put forward by the author were not, so far as the designs showed, representations of any ships now being built, and he, the speaker, was not prepared to support the design.

Admiral Boys spoke as to the effects of quick-firing and machine guns. He believed that these lighter weapons would not be effective against the hulls of the vessels when engaged in actual warfare, and that their object was to attack the upper works and crews. He believed that there would be no riddling of the ship at the water line by anything under the six-pounder quick-firing gun. As to hitting between wind and water, he thought there certainly was a chance of such an event happening, and a chance which should not be ignored. He instanced the engagement between the Kearsarge and Alabama. He would therefore prefer to have something to keep out such shots.

Mr. W. H. White followed. He said that he supposed the discussion should be reduced as to what is the best way to protect a narrow belt of the ship at the water line. Referring to the drawing on the wall, No. 3, he continued, this brings us to the question how best to prevent access to the triangular space where the armored deck slopes down to meet the side of the ship. Should this be done by vertical armor, by a sloping deck, or by coal, cork, stores, &c.? He would take it for granted that the trajectory of the shot would be practically flat. He did not believe that there was any mystic value in the few feet of the ship's side where the armor belt was placed. With eight degrees of roll the belt came right out of the water, and although there might be no intentional shot placed below the belt, there was a good chance of it. When the ship rolled towards the enemy a vertical projection of the deck of considerable height would appear above the belt. Quick-firing guns were rapidly extending in size. They had already a thirty-pounder and a forty-pounder quick-firing, and indeed were making a 6-inch gun on this principle; a weapon which would be armor-piercing to some degree. If they were to take the diagrams on the wall as representative of their class he was afraid they would be misleading to some degree. The deck in these designs was placed below water line, as shown in diagrams, but Mr. White drew in a fresh water line below the original one on the drawing, and this brought the horizontal part of the deck above water. This reduced the angular space between the sloping deck and the side of the ship to such a degree, that, as Mr. White stated, it was hardly worth mentioning, for 100 tons of coal would keep all the water out, and there would be no very sensible disturbance of trim if water were admitted. Taking these facts into consideration, the speaker said it was better to have the available weight thrown into the sloping sides of the deck than into the belt. The flat trajectory of modern projectiles, and the mass of coal that would be carried, were facts supporting this view. If the question of cost were brought in, it would be found that the armored belt would be five or six times more expensive. In speaking on the subject of a broader belt of armor the speaker said that if the mechanical and inventive genius of the country could be arrested so that no improvements could be made in quick-firing guns, then there would be something to say for thinner armor spread over a greater area. But such conditions do not apply, and were the weaker armor, more widely spread, to be introduced they would have the battle of guns and armor, waged during the last twenty-five years, to fight all over again, and finally we should only be where we now are. In conclusion, Mr. White wished to challenge Captain Fitzgerald's statement, that the whole opinion of the navy was on his, Captain Fitzgerald's, side. The speaker was acquainted with many naval officers, some of them well known gunnery officers, who held opinions more in accordance with those embodied in No. 3 design, with necessary modifications.

Admiral de Horsey rose to add a few words in explanation. The altered conditions of Mr. White's new water line might alter the whole aspect of the case and the opinions expressed. To this Captain Fitzgerald added an expression of approval. Mr. Biles, in his reply, said that Sir Nathaniel Barnaby had pointed out the basis of the whole question. The object of the paper had been to give a few details of the manner in which the most efficient vessel could be constructed for a given sum of money. As to the deck being above or below water that would make very little difference to the cost. His view was that the water line, for the purposes under consideration, was not a little bit of the side of the ship, but a pretty big piece of the side, and he did not think it a great matter whether the deck was a little above or a little below the still water load-line in one given condition of loading. Most of the points he had noted down for reply had been dealt with either by Sir Nathaniel Barnaby or Mr. White, so there was very little for him to say.

IX.

NAVAL MANŒUVRES, 1886.

While nearly all naval powers have caused a portion of their fleets to be mobilized for purposes of instruction during the past year, the French and English naval manœuvres of 1886 have been distinguished by the strength of the squadrons employed and the scope and varied nature of the operations carried on, and these only are described in this article.

The advantages of maintaining such squadrons for the instruction of naval officers in naval warfare, tactics, the management of vessels, and the intricate machinery and appliances with which these are now equipped, must be apparent to all, and should induce the formation of a squadron of evolutions of our own, composed of the most modern vessels available. Such a squadron would naturally form the practical naval war school and supplement the teachings of the War College.

FRENCH.

The last number of the Publications of this Office (V) described the first period of the operations of the French squadron of evolutions in May, 1886, detailing the gathering together of vessels at Toulon from the different ports of France, the stormy voyages of the torpedo-boats from the Atlantic, the rules governing the actions of ships and boats, and the manœuvres which took place off Toulon.

These formed the first period of the grand manœuvres and were divided into two parts or themes:

(1) Toulon not being defended by batteries or mines, but by a flotilla of torpedo-boats only, can a squadron of armored vessels bombard the place with impunity?

(2) A squadron of armored vessels blockades the port of Toulon, in which is found a flotilla of torpedo-boats, three cruisers, and an armored coast-defense vessel; can it prevent the forcing of the blockade?

The operations taking place under these themes were described, and the article closed with the close of the first period, May 18, 1886.

SECOND PERIOD—GRAND NAVAL MANŒUVRES, 1886.

First theme.—A squadron of armored vessels at anchor on the coast of Provence receives an order to double Cape Corso; a flotilla of torpedo-boats supported by a coast-defense vessel and three cruisers will endeavor to stop it, to destroy it if possible, and finally to pursue it.

VESSELS TAKING PART IN THE FRENCH NAVAL MANŒUVRES.

Admiral Lafont's squadron of armored vessels.

Vessels.	Launched.	Maximum speed.
		Knots.
Amiral Duperré	1879	14.5
Dévastation	1879	15.2
Vauban	1879	14.3
Redoutable	1876	14.7
Colbert (Flag)	1875	14.5
Friedland	1873	13.3
Richelieu	1873	13.1
Suffren	1870	14.3
Marengo	1869	13.5
Couleuvrine (unarmored torpedo-despatch vessel)	1885	18
Milan (cruiser)	1884	18.4
Hirondelle (dispatch vessel)	1869	15.6
2 torpedo-boats.		

Admiral Brown's Division.

Vessels.	Launched.	Maximum speed.
		Knots.
Fulminant (armored coast-defense vessel)	1882	13.2
Aréthuse (cruiser)	1882	16
Du Petit Thouars (cruiser)	1874	15
Desaix (cruiser)	1866	14.2
20 torpedo-boats.		

Admiral Lafont was in the Gulf Jouan (near Cannes) when the commencement of operations was announced, June 2. From this time seventy-two hours were allowed him to double Cape Corso and continue his route to the anchorage of Ajaccio, passing to the eastward of the island of Corsica and through the Straits of Bonifacio; thus circumnavigating the island.

Admiral Brown had gone to Villefranche from Toulon, leaving two groups (four each) of torpedo-boats at Antibes. Then gathering his entire force he proceeded, on the 1st, to Macinaggio, near Cape Corso, where immediately upon his arrival, at 6 p. m., he made such dispositions as seemed to him most desirable for barring the passage of his adversary. The Du Petit Thouars with four torpedo boats was sent to the westward to watch and harass the squadron, and report its movements to the admiral.

On the 2d June, towards 5 p. m., Admiral Lafont got under way and steered to the SE. At the time of starting no vessel of the enemy was in sight, but toward 7 o'clock the Du Petit Thouars and four torpedo-boats were sighted.

At nightfall, when some thirty miles off shore, the admiral changed course to the southward. The Du Petit Thouars and its convoy were lost sight of, but reappeared from time to time. With the idea of drawing this force away from its main body, Admiral Lafont continued on a southwesterly course until opposite the Gulf of St. Florent, when at 10 a. m. of the 3d he came about and directed the Duperré to give chase to the Du Petit Thouars, then some 5 or 6 miles distant. The Duperré gained upon her chase about half a mile an hour, so that at 6 o'clock she opened fire with her barbette guns at 2,200 metres range, and continued this until within 1,200 metres, when she sheered to port, delivered the fire of her starboard broadside, and hauled off; for at this moment Admiral Brown, who had left Macinaggio, came out from Cape Corso with the Desaix, Aréthuse, and a number of torpedo-boats to the relief of the Du Petit Thouars. The Duperré declined further action with these except by opening on the boats (which remained at some distance) with her secondary battery, and steamed off to the northward, thus somewhat distracting attention from the main body.

According to the rules the Du Petit Thouars was *hors de combat.*

The Hirondelle at this time was cruising near Giraglia (a small island off the northern end of Corsica), and the Milan near the Gulf of St. Florent—to observe the enemy and to attract the attention of his torpedo boats. Having in a measure succeeded in this, they rounded the cape at full speed and proceeded to rejoin the squadron at the rendezvous agreed upon.

In the meanwhile the squadron of armored vessels had steamed to the northeast, and when to the north of Cape Corso, and about 15 miles from Giraglia, the admiral steered to the southward and eastward at 10 knots speed, with the Couleuvrine and torpedo boats 71 and 74 thrown forward as scouts. At 3.30 a. m. of the 4th the passage of Cape Corso had been accomplished without sighting the Fulminant or either of the cruisers. Only four of the enemy's torpedo-boats were seen; one by the Colbert and Friedland, the other by the scouts.

In the encounter with these it seems, from the evidence, that the torpedo-boats could not have succeeded in effectively discharging their torpedoes under the fire of the ships.

The squadron continued its course to the southeast, through the Piombino Channel, and through the Straits of Bonifacio at 8 a. m. of the 5th, without encountering any of the enemy's force.

The first period of hostilities expired on the morning of the 5th.

On the 6th Admiral Lafont moored his squadron in the harbor of Ajaccio, without losing any of his vessels during the passage from the Gulf Jouan. It will have been noticed that the admiral had made more than one feint with his main force and scouts to deceive his opponent and draw off his forces. In this he appears to have been successful, for the passage of the cape was finally made with but little opposition.

If the squadron, upon the close of this period of operations after circumnavigating the island of Corsica, reached the port of Ajaccio intact, the division of torpedo-boats had not been so fortunate. While crossing the bow of the Desaix at full speed on the evening of the 3d, No. 66 collided with No. 64, the buffer spar of the former piercing the hull of the latter, whose injured compartment quickly filled with water. The boat, however, thanks to its pumps and water-tight bulkheads, reached the shore, about three miles distant, when she sank in two fathoms of water. The Aréthuse remained near the wreck and on the arrival of two wrecking tugs from Toulon the boat was raised. This and other lesser incidents somewhat hampered the operations of the torpedo division and made the passage of the squadron more easy.

The squadron made the passage of the cape at night in safety, and had it attempted it by daylight, which at this season lasts 18 hours, the chances would have been the more in its favor; for a day attack from torpedo boats upon such a squadron must be comparatively hopeless. The result of the operations under the first theme for the second series must then be regarded as being against the chances of a flotilla of torpedo-boats and supports preventing the passage of a strait by a squadron of armored vessels.

Upon their arrival at Ajaccio the vessels of the squadron coaled and made preparations to lay the boom and obstructions for the defense of the port, which were to be made during the three days' truce intervening between the periods of hostilities (from the morning of the 6th until 4 p. m. of the 9th). The squadron was moored in three lines, the vessels heading to seaward; as indicated in Fig. 3, Plate 1.

Second theme.—A squadron of armored vessels having taken refuge in an open roadstead upon the enemy's coast to repair damages or to give rest to its men takes measures to protect itself against an attack of torpedo-boats.

While the accompanying plate illustrates the principal features of the port of Ajaccio, the position of the vessels of the squadron, and the arrangement of booms and defenses, a further description of the adjacent coast may be desirable.

The Gulf of Ajaccio, one of the many bights on the west coast of the island of Corsica, presents a width of entrance of over 9 miles from the Sanguinaires Islands to Cape Muro, while its depth is about 8 miles, measured from the Sanguinaires Islands to the anchorage off Ajaccio.

Merchant vessels anchor, or tie up, behind the mole at Ajaccio; large war vessels, at the head of the bay, where the water is bold up to the shore.

From the end of the mole to the Scoglietti, the rocks off Pt. Aspretto, the distance is about 1,600 yards.

There is a narrow passage between these rocks and the mainland, through which 7 feet of water, sufficient for torpedo-boats, can be carried; but this requires a smooth sea and an accurate knowledge of the locality. The passage is impossible at night.

On the morning of the 9th the squadron placed the obstructions to bar the entrance of torpedo-boats. From the Scoglietti to within 400 metres of the mole a double hawser was stretched, supported at short intervals by ships' boats. In advance of this obstruction a line of clothes-lines was placed so that the propellers of torpedo-boats might become fouled before reaching the main obstruction. In rear, and near the flanks, were stationed steam launches armed with Hotchkiss guns. No mines were placed.

Such an obstruction would naturally be of little avail against an attack by heavy vessels, but by the conditions of the theme such vessels of the Brown division were restricted in their action to supporting and protecting the torpedo-boats, and the obstructions were made with this in view.

The passage, 400 metres wide, between the mole and the obstruction, was left open for the passage of the merchant vessels trading with the port.

At 3 p. m. of the 9th, Admiral Lafont made signal for the ships to get out their torpedo nets. Those vessels which were not provided with the regular Bullivant nets protected themselves with canvas, awning-curtains, tarpaulins, &c.; actual experiment having before shown that these improvisations were comparatively effective against torpedoes. At 4 o'clock the nets were in place. Their distance from the ships' sides varied from 6 to 9 metres.

The new period of hostilities began at 4 o'clock, and at that hour the lookouts and scouts were stationed. At night a scout, a torpedo-boat, and a steam launch patrolled the harbor and immediate neighborhood. The latter was relieved at 11.30, but the others continued their duty until sunrise.

During the first and third night the Couleuvrine patrolled in the offing, and the Hirondelle took her place during the second night. Twenty-four hours was the duration of this patrol duty, which, during the daytime, was extended beyond the gulf and into the offing. At night the electric lights of the different vessels were directed, as indicated in the plate, so as to sweep all parts of the harbor and its approaches.

The ships' companies were divided into three watches, and there were two officers on deck at all times (as described in No. V, on the operations off Toulon).

Let us now turn our attention to the torpedo-boat division. Bad weather increased the difficulty of raising the sunken torpedo-boat until the 7th. Wind and rain continued during the 8th, 9th, and 10th, delaying the departure of the torpedo-boats and causing loss of available time in which to attack. Finally, on the morning of the 11th, Admiral Brown, on board the Desaix, got under way from Macinaggio with the Fulminant and twelve boats, six of each class. The wind was still blowing strong, and the sea was running high; but the admiral wished to test the boats in bad weather. Two hours after starting it was found that the second-class boats (89 feet) were making such bad weather that signal was made for them to return to the anchorage. The Desaix was also laboring considerably, and her speed was reduced from 10 to 5 knots; but the first-class boats (108 feet) behaved well, and all reached Ajaccio in good condition. The Du Petit Thouars had preceded Admiral Brown by one day, to reconnoitre.

Towards 4 o'clock in the afternoon the Brown division was sighted by the Couleuvrine and reported to the squadron, which was now the more on the alert, not only from being aware of the arrival of the enemy, but from the fact that only one night remained in which the attack could be made. (Hostilities were to end on the 12th at 4 p. m.)

Admiral Brown, having been joined by the Du Petit Thouars, anchored behind the Sanguinaires about 6 p. m., and received the reports of officers as to the disposition of the squadron and its defense. His force available for attack had been reduced from twenty to six torpedo-boats, and he had lost the services of the Aréthuse (still remaining near the sunk torpedo-boat), and, to add to his embarrassment, the weather was now clearing and the moon shining bright. As the moon did not set until after midnight, the time of attack was necessarily restricted to the short interval between that hour and 3 a. m., at which time the day broke.

The weather at midnight was clear and calm, with occasional light airs.

At 12.40 the Couleuvrine signaled that the enemy was under way, and immediately the electric lights of the squadron lit the harbor.

At 1.05 the approach of the enemy was signaled.

At 1.45 a torpedo-boat made an attack upon the Hirondelle, but received the fire of the Hotchkiss guns of the squadron, and would doubtless have been disabled or destroyed before firing a torpedo effectively.

At 2.05 the Fulminant (now flagship) was discovered in the direction of the Scoglietti accompanied by the torpedo-boats. Under the electric lights her form, turret, and other details were readily distinguished. She steamed close up to the boom and sent forward two boats with the intention of grappling the obstruction, which, when grappled, was to be bodily towed or torn away by the ship. The boats, however, were constantly under the squadron's fire and could hardly have accomplished their purpose.

At this time the torpedo-boats made the principal attack. Four attacked by the passage left open, the fifth became entangled in the obstruction, while the sixth received some slight damage to her machinery and was not ready at the time of the attack.

Three of the first mentioned boats attacked at moderate speed, in full sight under the search lights, and were constantly under fire. The evidence seems sufficient to show that they were unsuccessful, and that in cases where the torpedoes were signaled by the boats as having been successfully discharged (by burning a blue light) the range had been much underestimated. The fourth boat, under the command of Lieutenant Duboc, of Sheipoo fame, took advantage of the Hirondelle's search light being directed to the southward of the mole to attack, at 2.20, at full speed, under cover of its shadow. His attack was probably successful, as the Hirondelle fired but three shots at him before his torpedo was discharged, when he steamed into the offing.

At 2.25 the Fulminant withdrew, and the attack was over.

At 2.50 the search lights were extinguished, and day began to break.

While there still remained twelve hours during which hostilities were to last, any day attack would have been hopeless. The second period of operations was therefore closed.

The electric search lights are reported to have served with twofold effect; they not only effectually lighting the harbor and entrance, but their intense light blinded the approaching enemy, and rendered all estimate of distance extremely difficult. It was again shown that search lights should be carried as low as practicable in order to secure their greatest efficiency.

The attack was a failure, and it must be admitted that the chances were against the torpedo division. The weather had been extremely bad, the number of boats reduced to six, and the only night on which the attack could be made was brightly lighted by the moon until midnight. These, however, are the chances which the torpedo-boats must expect, and must take. But, on the other hand, in actual war, there might have been the chance of destroying the obstructions by ramming them with the supporting ships, which would have opened the way for the boats and made their task somewhat easier.

On the 15th the squadron, re-enforced by the Richelieu, sailed for Oran, Algeria; and on the 16th the Brown division returned to Toulon, preparatory to carrying out the third and last series of operations.

THIRD PERIOD.

The forces taking part in the operations of the third period were the same as before, except that Admiral Brown's division contained but thirteen torpedo-boats, all of the first class (108 feet); the second-class boats being considered unsuited for operations on the high sea. Admiral Lafont's squadron was at Oran, and Admiral Brown's division at Toulon, when the period of operations began on the 25th of June.

The theme was as follows:

Theme.—A squadron coming from Gibraltar to attack Toulon or Marseilles is obliged to pass through the Balearic Islands, within a belt comprised within two parallel lines 28 miles apart, so drawn as to pass between Iviça and Majorca, and touching the island of Dragonera; when within 15 miles of the French coast the squadron will be considered as free from attack. A division of torpedo-boats will endeavor to attack the squadron while *en route*, and prevent its passage.

Naturally, the torpedo-boat division took station to the southward of the Balearic Islands, near the prescribed pass, in order to make sure of intercepting the squadron.

On the 25th, at 1 p. m., the squadron got under way from Mers-el-Kebir (Oran), and stood to the NE., in echelon of vessels. The speed was set at 6.2 knots. The Couleuvrine and the two torpedo boats, 71 and 74, were taken in tow by the armored vessels.

On the 27th, in the early morning, the Aréthuse was sighted, with upper masts housed. At 6.30 a. m. she was still in sight to the NW., distant about 16 miles, and evidently watching the squadron. At this hour the squadron changed course to the SW., and housed its upper masts. At 10.45 Admiral Lafont made signal to start fires in all the boilers.

At noon the position of the squadron was latitude 37° 15′ north, longitude 1° 06′ east, about 90 miles from Formentera. The torpedo-boats were cast off and coaled.

At 1 p. m. the squadron steered NNE., and the speed was set at 10.5 knots.

Notwithstanding the sea was calm, the sky overcast, and the squadron sighted by one of the enemy's cruisers, Admiral Lafont decided to attempt the passage that night.

The Brown division was in the neighborhood of Dragonera on the afternoon of the 27th, and at nightfall it steamed to the southward, at about 8 knots speed, in four groups. On the left of the line was the Aréthuse with three torpedo boats, in the centre the Du Petit Thouars and Desaix, each with three boats, while on the right was the Fulminant with the remaining torpedo-boats. The plan of watching, or patroling, adopted by Admiral Brown, was to steam in line to the southward at night, and in the day-time to retrace his steps to Dragonera, so as to insure discovering and attacking the squadron at night.

At 9 p. m. the squadron took in its running lights and steered North upon making the Formentera light. At midnight the lights of the Aréthuse and torpedo-boats were sighted.

At 1 o'clock the engagement took place, between Iviça and Majorca. No. 72 attacked the Redoutable, and though fired upon by that vessel and the Suffren, it succeeded in getting within effective range, when it burned its blue light. Another of this group, No. 27, is said to have discharged one torpedo at a passing merchant steamer, and a second torpedo at its convoy ship, the Aréthuse. The Du Petit Thouars and group did not sight the squadron until the search light of the Colbert was turned on the passing merchant steamer; then the cruiser gave the alarm, but its boats did not succeed in attacking.

Admiral Lafont sent back his torpedo-boats for the protection of the rear ships, and increased the speed to 11.5 knots.

The torpedo-boats of the Brown division gave chase, but at daylight they were not in sight.

The squadron steered for the Planier light, and at 12.30 a. m. of the 29th sighted it. At 3 a. m. the 15-mile limit (from the coast) was reached;* the squadron was free from further attack, and at 8 a. m. moored in Toulon harbor. It was delayed off the Planier by an accident to the machinery of the Richelieu, which vessel had been in commission only a fortnight.

Admiral Brown, after the passage of the squadron, had gathered his division together by 10 a. m. of the 28th. The Du Petit Thouars and group reached Toulon at 9 a. m. of the 29th, but the other groups did not arrive until 3 p. m.

The results of the attack of the torpedo-boats upon the squadron seem to have been as follows: The Redoutable struck by a torpedo; the Aréthuse struck by a torpedo from one of its own boats; a passing merchant steamer fired upon by a torpedo-boat; and, as claimed by the torpedo-boats, the Richelieu struck by a torpedo, although there is little evidence to support this.

A notable fact is brought to light by this period of operation, viz, that the torpedo-boats which on trial made 20 knots could not overtake a squadron making 11.5 knots. This was due to the fact that the boilers of the torpedo-boats had been become so dirty during their four-days' cruise as to make it impossible to get the required steam.

CONCLUSIONS.

Off Toulon (1st period) the torpedo-boats were unable to drive off the squadron of armored vessels or to seriously interfere with the bombardment of the town (supposed to be without other defenses than the torpedo division), the squadron having attacked by day in a sea which did not seriously disturb the accuracy of its fire, but rendered the discharge of torpedoes from the torpedo-boats difficult, if not impossible.

Off Toulon the torpedo division was unable to break the blockade of the port, although it was claimed that the Desaix escaped. Torpedo-boats must naturally increase the anxiety of a blockading squadron; but the nets with which armored vessels now surround themselves under such circumstances greatly reduce the chances of torpedoes reaching them. Blockading squadrons must always be accompanied by swift cruisers and counter-torpedo boats to increase the chances of discover-

---

* The distance from Formentera to this limit is about 300 miles. The distance run from 2 a. m. of the 28th to 3 a. m. 29th was about 290 miles (knots).

Plate 1

Fig 1.

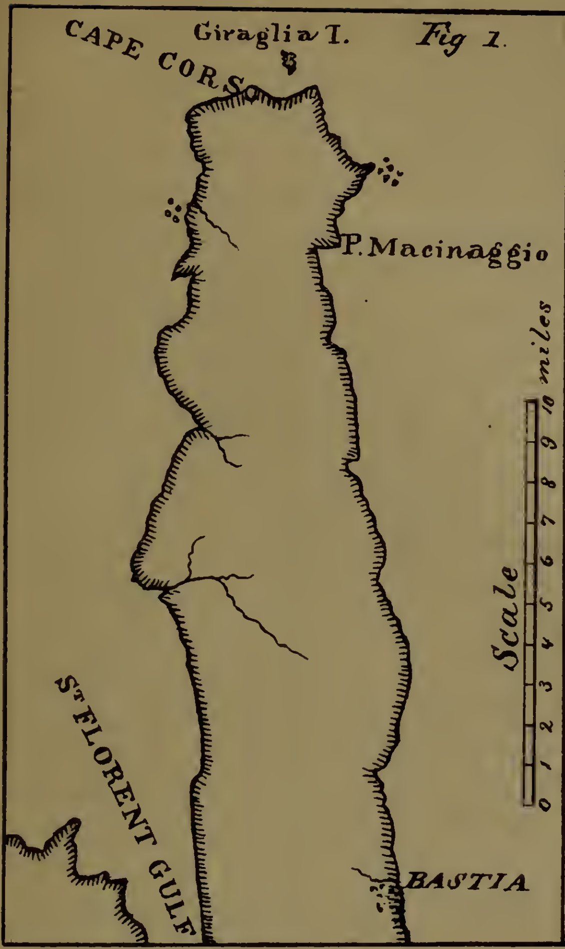


Fig. 2

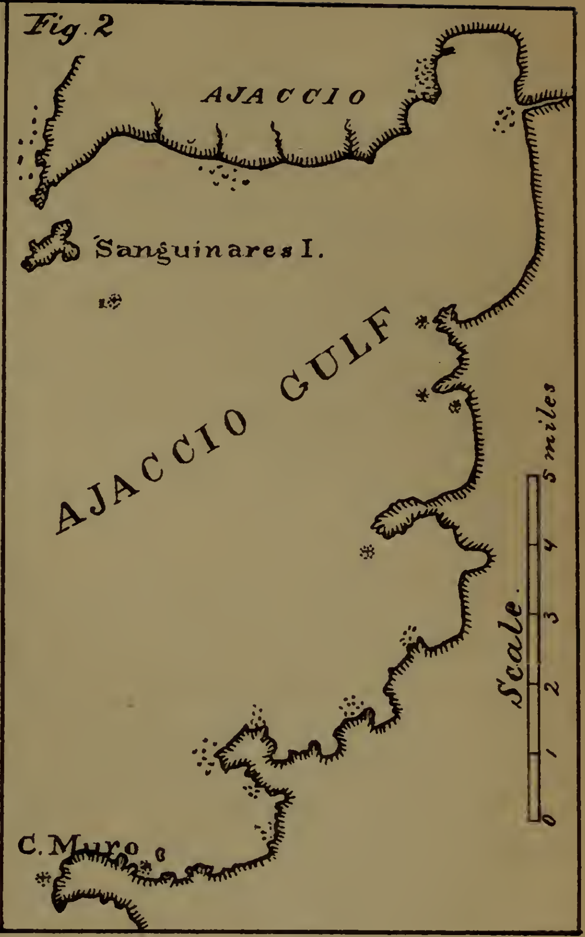


Fig 3

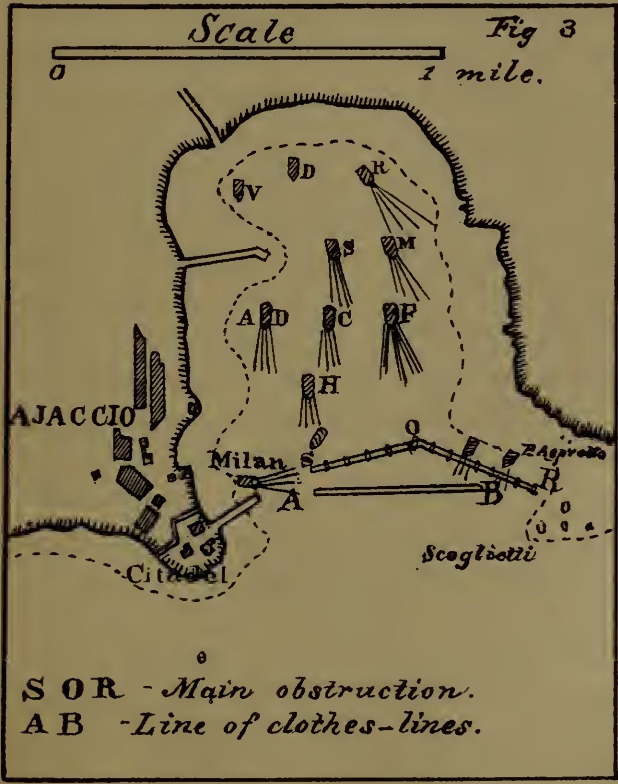
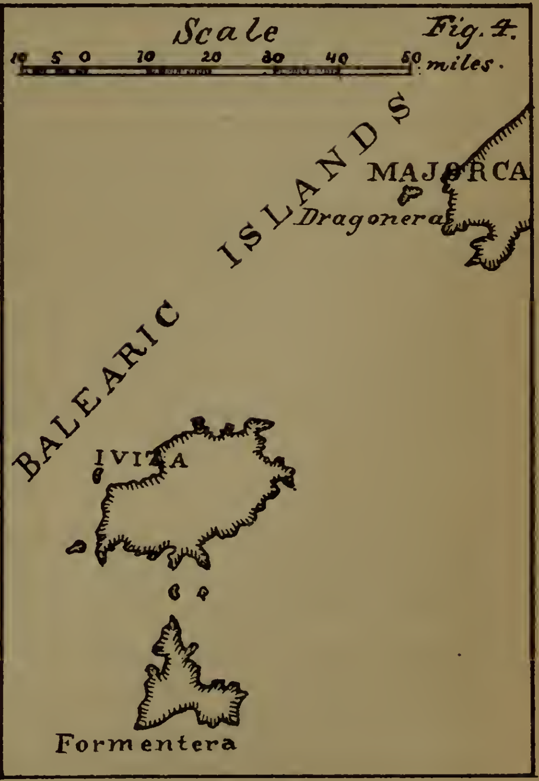


Fig. 4.



FRENCH OPERATIONS

ing and beating off attacking boats before getting within range of the heavier vessels.

For open-sea work the 89-foot boat proved altogether unsuitable, as shown in the second period of operations between Toulon and Ajaccio, and the chances of an effective force of 108-foot torpedo-boats reaching a remote destination in condition for prompt attack cannot be very great, unless undertaken during the fine seasons of the year.

The chances of a successful attack by a small number of torpedo-boats upon a squadron protected by booms, if well equipped and on the alert (as at Ajaccio), must be very small. And again, in operations similar to those of the third period, the advantage should be with the heavy vessels, if properly handled and informed of the enemy by scouts and lookouts. Doubtless in such a passage a squadron will suffer some loss; but it should be accompanied by its own torpedo vessels, which will deal with the enemy's torpedo-boats at a distance and reduce their chances of succeeding in their attack.

All parties in France, the torpedoists as well as the conservatives, are agreed that the French torpedo-boats in service a year ago were altogether too small and too frail for work at sea. The reduction of their speed in a sea-way is also very great, probably from 18 or 20 knots to 12 or 13. The new torpedo-boats now building, or completing, vary in length from 115 to 151 feet, and in displacement from 53 to 148 tons. (This does not include the 111-foot boats, numbered from 75 to 104.) The English learned this lesson a year earlier, and their newer boats are 125 feet long and 60 tons displacement. Other countries have still larger boats. (See p. 337.)

A special class of men must be trained for service in torpedo-boats, for with the gain of experience of the crew the increased efficiency of the boat is very marked. The outward voyages of the torpedo-boats from the Atlantic varied in duration from twenty to twenty-five days; while in returning from Toulon, Nos. 60 and 67 made the voyage to Cherbourg in eleven days and six hours, stopping 26 hours in Cadiz and 20 hours at Corunna; No. 29 made the voyage to L'Orient in nine days and three hours, stopping at Gibraltar, Lisbon, and Corunna; No. 71 made the voyage to Cherbourg in nine and one-half days. Of course the difference of season must be considered in making the comparison between the outward and homeward voyages; but this cannot account altogether for the reduction of duration of the voyages by more than one-half.

Admirals Lafont and Brown were called before the Budget Committee of the French Parliament after the manœuvres. They are reported to have testified as follows: That the torpedo-boats used were too small; the emplacement of their tubes should be altered from their present place in the stem to a higher position somewhat removed from the bow. (It was frequently found that in a sea-way it would have been impossible to open the torpedo tubes without danger to the boat, or at least without seriously impairing all accuracy of discharge, or even to get the torpedo in place in the tube.) It is said that these officers recommended the construction of armored vessels of from 6,000 to 8,000 tons displacement, and that they insisted upon maintaining a squadron of evolutions and instruction composed of vessels carefully chosen for the purpose.

A study of the manœuvres from beginning to end impresses the reader with an idea of the excellent organization of the French navy, the skill and training of its personnel, and the system, or programme, by which new constructions are made, so that when put in service the fleet will be homogeneous, capable of united action, and equipped with all classes of vessels necessary for the performance of the various duties imposed upon it. The maximum speed of the armored vessels, given in the tables, is remarkably uniform, and enables a fleet to maintain a fair rate of speed. The squadron of nine armored vessels (several of them old), and two cruisers, with torpedo vessels and boats, steamed in a prescribed order for more than twenty-four hours at a speed of 11.5 knots. It is thought that no other nation could, at that time, have assembled a squadron of armored vessels of the same number which could have steamed in squadron at that speed for that length of time. Speed has but recently become the great desideratum, and the new armored vessels now coming forward will make the movements of squadrons much more rapid; but in organization, construction, training and drill, painstaking details, experiment, and the maintenance of a formidable squadron of evolutions in which to teach the art of war, the French Navy is unsurpassed and commands the respect and attention of the naval student.

ENGLISH.

The English naval manœuvres of the summer of 1886 may be divided into three distinct series, illustrating different questions or phases of naval warfare:

(1) The manœuvres of the Channel squadron, near Portland and at Bantry Bay.

(2) The manœuvres of the Reserve squadron, at Bantry Bay.

(3) The combined bombardment, attack, and defense of Milford Haven, in which the naval and land forces took part.

The vessels taking part in these manœuvres have already been sufficiently described in former numbers of this series to indicate their relative fighting capacity, so that their names are merely given at this time to indicate the composition of the squadrons.

Channel squadron.—Vice-Admiral Hewett, commanding; Minotaur (flag), Agincourt, Iron Duke, Monarch, (all armored); Valorous, torpedo-depot ship (replacing the Hecla), and torpedo-boats Nos. 2, 3, 4, 5, 12, 14 (86 feet), 23, 24 (113 feet).

Reserve squadron.—Rear-Admiral Baird, commanding; Hercules (flag), Ajax, Shannon, Penelope, Northampton, Hotspur, Devastation, Rupert, Belleisle, (all armored); torpedo-boats 31 and 34 (125 feet).

MANŒUVRES OF THE CHANNEL SQUADRON.

Torpedo warfare furnished the theme for this set of manœuvres—torpedo-boat attacks, searching with the electric light, countermining, removing obstructions, and torpedo practice being the topics receiving attention.

The torpedo-boat flotilla devoted the first week to exercise in firing (furnaces), handling the boats separately, and torpedo practice.

On the 21st June the torpedo-boats went outside, at 10 p. m., with the intention of attacking and testing the efficiency of the search lights of the squadron to discover them. Immediately after their departure these lights were brought into action and searched the approaches. Nothing was discovered until after midnight, when one division of boats was seen creeping through the western entrance under the land, while shortly after the remaining division was sighted coming round the breakwater.

During the night two long lines of countermines, 180 yards apart, were run from the ships, in a westerly direction.

On the 22d the Iron Duke got under way and stood outside at full speed, 3 miles in advance of the torpedo-boats which were to attack her. The boats were divided into two divisions, the fastest leading. As the two leading boats of the first division reached a position abreast of the Iron Duke she turned toward them and opened fire, putting them out of action. She then turned upon the other two boats, with the same result. In the meanwhile the leading boat of the second division had, under cover of the smoke, got within range, and was in the act of discharging her torpedo when discovered by the ship. By a quick use of the helm the Iron Duke is reported to have dodged the torpedo, and to have opened with her broadside upon the boat, causing its destruction. The other boats were judged out of action before getting within effective torpedo range.

On the 23d the torpedo-boats were exercised at firing torpedoes at a mark. At 1 p. m. the Iron Duke again went outside to receive another day attack by torpedo-boats. Her speed was 9 knots. The result was the same as on the previous day. Upon returning to the harbor at full speed she was fired at by a torpedo-boat, No. 23, when abeam. The torpedo was avoided by the use of the helm. This was twice repeated, with the same result.

To judge these manœuvres, an umpire was appointed for the ship and for each boat, and a referee decided questions in dispute. The following were the rules for putting boats out of action:

Any torpedo-boat will be judged out of action when, under the fire of heavy guns, it receives 10 rounds at 2,500 yards, or 2 rounds at 700 yards; or is under fire of rapid-fire guns 2½ minutes at 1,500 yards; or is $1\frac{1}{2}$ minutes under Nordenfelt fire at 1,000 yards, or machine-gun or small-arm fire at 450 yards.

On the 25th, the Monarch having got under way, the torpedo-boats placed themselves to attack her. No. 12 fired at her a torpedo (fitted with firing-pin and detonator), which hit near the stern, and immediately after a violent shock was felt in the ship, which was believed to have been caused by the explosion of the torpedo air-chamber on being struck by the ship's propeller. The torpedo was not found upon searching for it.

The Iron Duke, with torpedo-nets in position, was then attacked while under way at low speed. One torpedo struck the net, and it is stated that two others struck in the same spot, which, if true, would have been disastrous in actual service.

On July, 30, at Berehaven, countermining and obstruction-removing were practiced. All the ships sent their countermining-launches, and creeping and sweeping boats to the Iron Duke. Upon arriving in the neighborhood of the mine field, the sweeping-boats were sent in to sweep the channel for submarine mines in front of a boom. The creeping-boats were next sent in as far as the boom, creeping for the cables, and breaking those found. Two countermining-launches were then sent in in tow of steam launches; these placed their countermines, retired, and passed the cables to the Iron Duke, which exploded them. This done, two boats were sent in to explode charges of gun-cotton on the boom to break it. When fixed, the boats retired and exploded the charges; one charge cut the boom clean through; the second broke the spars, but did not cut the chain binding them together.

The Iron Duke then occupied the space cleared by the countermines, sent forward the creeping-boats, and afterward the counterminers, beyond the boom. When this set of countermines was exploded the ship passed through the break in the boom.

The Channel squadron continued its cruise, carrying on different operations in the ports visited, until arriving at Milford Haven, where it took part in the attack of that place.

MANŒUVRES OF THE RESERVE SQUADRON AT BANTRY BAY.

The reserve squadron arrived at Bantry Bay on June 21. Previous to his arrival, Admiral Baird had issued a memorandum indicating the nature of the intended manœuvres and the work to be done. That these were totally different from the manœuvres of the Channel squadron will be seen by Admiral Baird's memorandum, as follows:

> (1) The fleet is in a close harbor and about to take offensive operations at sea. To carry out this, the vessels are to be prepared for action with only lower masts and yards up, the tophamper being sent down.
>
> (2) The fleet will be supposed to have arrived in harbor for the purpose of coaling, provisioning, &c.; there being a vigilant enemy outside. The entrance to be protected with mines and a boom, the ships rigging their defense-nets.
>
> In the first case, the ships are to be prepared according to the circumstances, each ship being ready with all her guns and torpedoes clear,

In the second, the following details are ordered:

(*a*) Each ship will fit and lay out one line of electric contact mines and three boat-mines;

(*b*) A boom will be laid across the western entrance. It is to be made from the ships' spars and stores, without interfering with the torpedo-booms and defense-nets. The details of the booms are to be left to the discretion of the commanding officers, who are to prepare the best defense they can with the means at their disposal. The masted ships are each to prepare 100 yards of boom, the turret ships 40 yards. The boom defense is to be carried out under the supervision of the captain of the Shannon.

Each ship will have her mines ready for laying on arrival, tested, and as far as possible joined up. The firing station will be a hut erected on shore by the carpenters of the fleet. After the mark buoys are laid, soundings are to be taken by each ship at intervals of 20 fathoms between the buoys, and the mooring ropes so adjusted that the electric contact mines will be 3 feet below the surface of the water.

Bantry Bay was described in the last number of this series (p. 5), so that no further description will be here given. The squadron anchored in two columns in the western part of the harbor, the Shannon and Penelope bringing up the rear, eastern end, of the columns, the Hotspur and Rupert leading, while the Belleisle took a position in advance of and opposite the interval between the columns.

The boom was thrown across the western entrance, and was protected by a mine-field in front (to the north) and guarded by ships' boats in its rear. The defense at the eastern entrance depended entirely upon ships' boats, twenty-five in number.

The enemy consisted of two torpedo-boats and nine steam launches fitted with torpedoes. These boats withdrew to the southern shore of Bere Island.

The attack was ordered for the night of the 25th.

At 9 p. m. the vessels placed their torpedo-nets and the boats were manned and sent to their stations. The Hotspur and Rupert, with four boats, watched and defended the boom; the remaining twenty-five boats, stationed at intervals of 100 yards, guarded the eastern entrance. The search lights were constantly used after dark to light the approaches.

At 11.40 an attack was signaled from the west. This was a feint, and the single attacking boat was driven off. At 12.45 the main attack took place from the east. The two torpedo-boats succeeded in eluding the guard-boats, taking advantage of the cover of two merchant vessels at anchor in the harbor, and fired three torpedoes at the Shannon and Penelope. Two torpedoes were found in the latter's nets, and one in the former's. Some of the launches were captured, but the majority got through the line of defense on account of the superiority of their speed over that of the cutters, &c. The launches, however, did not succeed in hitting with their torpedoes.

The attack ended at 2 o'clock. Great difficulty was found in determining which boats belonged to the enemy and which to the squadron, and this would have led to great confusion in directing gun fire.

The rule adopted for disabling or capturing boats was that if under the fire of two rounds from a heavy gun within 800 yards, or a boat's guns within 100 yards, they should be considered out of action.

On the 26th the Belleisle rammed and easily cut through the boom, and proceeded to bump the mine-field, which gave evidence of having been properly laid.

The boom was dismantled and mines removed on the afternoon of the same day.

THE COMBINED MANŒUVRES AT MILFORD HAVEN.

(Plate 2.)

The third set of operations, near Milford Haven, illustrated a novel feature in sham warfare, the defense of a fortified seaport against the attack of a fleet. The advantages of such operations are most apparent, and have never been undertaken on such a scale as on this occasion. The equipment of the fleet, the resources of the officers, and the training of the men were tested; while with the defense an opportunity was afforded for ascertaining the readiness of forts, mines, and electric plant for action, and for instructing regular troops and volunteers in searching with the electric light, handling mines, and serving their weapons, of whatever nature, in the smoke, at least, of an enemy's fire.

The general plan of operations was arranged by a board of officers from the Admiralty and War Office.

The attacking fleet was under the command of Vice-Admiral Hewett, with Rear Admiral Fremantle second in command. It was composed of the Minotaur, Agincourt, Sultan, Monarch, Iron Duke, (armored vessels); Hecla (torpedo-depot ship); Medina, Medway, Spey, and Tees (gunboats); four first-class torpedo-boats, Nos. 23, 24, 25, 31, and several smaller ones.

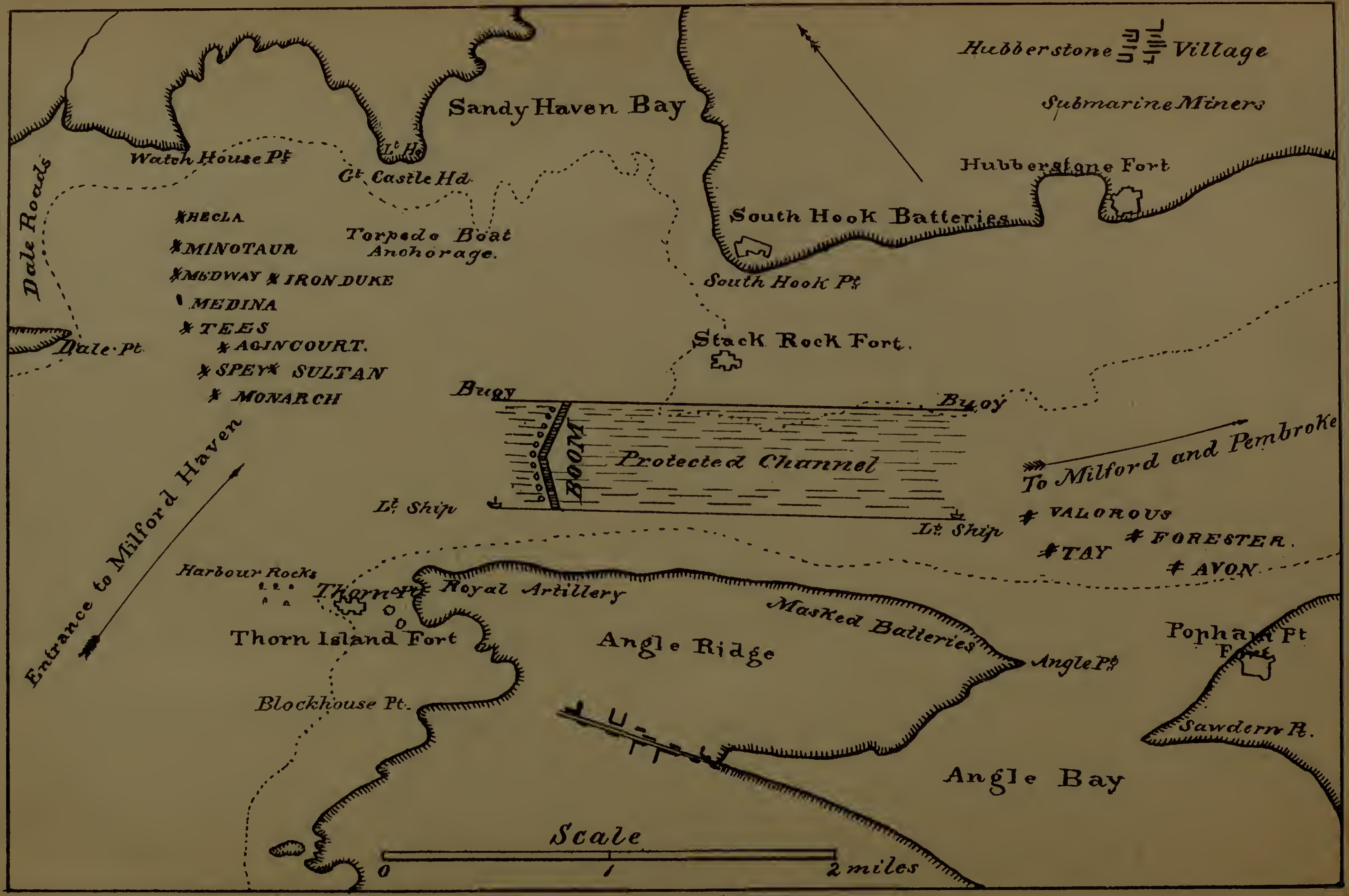
By agreement the channel was limited to an area 3,000 yards long by 700 wide; all other parts of the harbor were considered as land, or closed and inaccessible. The southern edge of the channel was marked by light-ships; the northern, by Stack Rock Island and buoys.

The channel was defended at its entrance by a boom made of 12-inch timber, moored by heavy chains, with its centre somewhat in advance of its wings. Fields of electric-contact, observation, and other mines were placed both in front and in rear of the boom.

The forts at Stack Rock and South Hook and the masked batteries on Angle Ridge covered the channel with their guns. At Angle Ridge detachments of infantry represented batteries of machine-guns.

The defense, under the control of Major-General Lyons, consisted of detachments of artillery, infantry, and engineers; a detachment of volunteer mine-layers from Greenock, Newcastle, Liverpool, and Cardiff; three gunboats, the Avon, Tay, and Forester, under the command of a commander in the navy, and manned by naval artillery volunteers from London, Liverpool, and Bristol; six second-class torpedo-boats, Nos. 2, 3, 4, 5, 12, 14, and six steam-launches (representing fast steamers armed with machine-guns); all commanded by naval officers.

Plate 2



Operations at Milford Haven

The forts and batteries were armed as follows: The Stack Rock fort, 21 10-inch and 5 9-inch M. L. R.'s; South Hook batteries, on the north shore, 15 7-inch and 5 9-inch M. L. R.'s; on the Angle Ridge masked batteries. The Blockhouse fort, and the forts on Thorn Island, Hubberstone, and Popham Points did not take part in the operations.

Umpires were appointed by the Admiralty and the War Office to judge the operations under the rules laid down. The chief umpires were a general of artillery and a naval captain, and under them were a large number of sub-umpires from both services. The chief umpires observed the operations from Stack Rock fort; the sub-umpires were stationed at different points, in the boats and vessels.

The following rules were adopted:

Umpires are to consider themselves as such not only for their own posts, but for the whole field of operations as well.

Each boat will, if possible, carry a sub-umpire, who shall have authority over his own boat, or any other in which there is no umpire.

Any ship passing within the radius of destructive effect of a torpedo, or feeling the shock of explosion of a mine, will be considered *hors de combat.*

Any gunboat, torpedo, or other boat, feeling the effect of explosion of a mine near it will be ruled out of action. Such vessels or boats will at once retire from the mine-field to the rendezvous of disabled vessels by the most direct route.

Gunboats, torpedo-boats, and ships' boats being under fire by day for a sufficient period to be judged by the umpires according to circumstances, or if under artillery fire while within the beams of the searchlight, will be ruled *hors de combat.*

Torpedo-boats, or other boats will be liable to be put out of action, under certain specified conditions, if engaged with an enemy's boats within a distance of 30 yards.

Any boat succeeding in attaching an explosive charge to any part of the boom shall be free from attack until the charge is exploded (or has missed fire), which (former) fact will be signaled by a rocket by night or by a red flag by day. In case of miss-fire the boat cannot replace the charge, nor can it take any further part in the operations.

Boats put out of action in the preliminary operations may still take part in the main attack.

The preliminary operations to be considered as ended when the leading ship crosses a line between Watch House Point and Blockhouse Point.

On Saturday, August 14, the squadron left Holyhead and proceeded to Bride's Bay, leaving the latter on the 16th, and arriving off Milford Haven the same day.

The sea was rather rough and too heavy for the torpedo-boats, so that signal was made that no operations would be undertaken during the night. On shore the fleet was sighted soon after noon and everything made ready to meet the attack. On Tuesday evening, the 17th, the boats of the defense made an attack upon the squadron, which was repulsed by the fire of the Iron Duke, Sultan, and Monarch. At 9 o'clock a second attack was driven off.

The armored vessels then got under way and opened fire on the forts at long range. The wind, being from the southward, blew the heavy smoke from the vessels up the harbor, and under its cover the boats (some sixty in number) were sent forward to remove the obstructions. Several engagements took place with the boats of the defense, but these were obliged to yield to superior numbers and retreat. Countermines were placed and the signals made to show that a portion of the obstructions had been removed.

On shore the search lights of the Stack fort and South Hook lighted the field of action, but the lights from the squadron directed upon the batteries blinded the gunners, already hampered by the smoke, and made aiming impossible. (The same effect was noted in the attack at Ajaccio, p. 218.) The management of the search lights is said to have been much more effective on board the vessels than from the shore.

Some of the torpedo-boats of the defense succeeded in approaching vessels of the squadron, but their attack was judged unsuccessful by the umpires, as the vessels had their nets down and received the boats with a heavy fire.

Shortly after midnight the Seahorse was discovered in an attempt to ram the boom. She received a heavy fire from the batteries, and by some accounts is said to have been ruled out. Her commander, however, did not propose to be stopped by such means, but passed the outer mine-field, smashed the boom, and, after exploding a contact-mine, withdrew from action. A gunboat followed the Seahorse, with instructions to perform the duty assigned the latter in case of failure on its part.

The countermining boats then worked into the inner mine-field. After this had been countermined the Iron Duke got under way and steamed through the obstructions up to Stack Rock fort.

The attack had made considerable advance during the night's work, and morning showed the countermines well placed close up to the boom (so as to have exploded at least four mines), the boom destroyed in several places, and a break made through it by the Seahorse large enough for the heavy vessels to pass. The principal tactical points of interest are: First, the choice of position from which the squadron bombarded, so that the smoke was carried into the harbor, and under its cover the boats and countermines were pushed forward; and, second, the skillful management of the squadron search lights in blinding the gunners on shore, and so disconcerting the fire of the batteries.

Naval officers criticised the construction of the boom which had yielded to the shock of so small a vessel as the Seahorse. The boom was built by a contractor under the direction of the army engineers, and, while not inherently strong, it was probably further weakened by the depth of water (25 to 60 feet) and tidal currents.

The search lights on shore were not so well managed as those of the squadron. Those on Stack Rock were extinguished after a short time, while those on the north shore did not work well.

At 9 p. m. of the 18th the attack was renewed. The squadron got underway, stood in and anchored farther up the channel.

The defense's flotilla being considerably reduced, the process of countermining, creeping, and sweeping was made more easy. The tactics of the squadron were similar to those of the night before. The search lights were used to blind the gunners on shore and the smoke was used as a cover for the countermining boats, which laid one line of countermines of 90 feet destructive radius the whole length of eht passage (It is doubtful if the width of channel opened would have been sufficient to permit the safe entrance of a squadron.) The clearing of the channel occupied about two hours. The operations here came to an end.

The manœuvres described when considered as parts of a whole series furnish a most admirable lesson in the practice of naval warfare. The programme was comprehensive and practical, and embraced the following questions or exercises:

(1) Training of crews in the handling of torpedo-boats and their appliances.

(2) Torpedo target practice at fixed marks.

(3) Tactical considerations of day and night attacks by torpedo-boats.

(4) Torpedo target practice at vessels moving at full speed.

(5) Searching with electric lights.

(6) Laying booms, obstructions, mines of various character for purposes of defense.

(7) Removing obstructions by sweeping, creeping, countermining, and ramming.

(8) Determining the value of torpedo-nets as a means of defense for vessels at anchor.

(9) A naval attack upon a port defended by forts, mines, and obstructions.

CONCLUSIONS.

(1) The necessity of protecting a boom by sufficient mine-fields, outer and inner, was again shown.

(2) The efficiency of such mine-fields for delaying the advance of a fleet is great. While liable to be countermined or removed the conditions of wind, sea, and darkness must be favorable for such work, and the delay necessary for their removal may be of the greatest value to the defense.

(3) The efficacy of the electric lights for blinding and confusing the aim of gunners firing in face of it was again apparent. The lights should be as low as possible to act most effectively, and should be as numerous as possible, whether their emplacement be afloat or ashore.

(4) The value of the cover of smoke for protecting countermining boats and obstructing the beams of electric lights was much commented upon.

(5) Booms however well built may be readily broken by ramming with a heavy ship, and if not protected by mine-fields offer but little obstruction to a fleet.

(6) The efficiency of torpedo nets for the protection of vessels when at anchor or low speed was shown.

(7) The uncertainty of hitting with the Whitehead torpedo during daylight, owing to the fact that the discharge and course of the torpedo may be seen and avoided by a handy vessel was indicated. (The French experiments of last year, described p. 19, Gen'l Inf. Series, No. V, are not in accordance with this.)

(8) The training and skill in countermining and obstruction-removing, as shown at Milford Haven, are worthy of emulation.

(9) The desirability and advantages of placing all the submarine and water defenses of a port under naval control has been conceded by representatives of both services in England.

In Germany the entire system of sea-coast defenses, forts, batteries, mines, torpedoes, as well as the fleet, are under the control of the navy, and are manned by it.

In France all the submarine defenses and many of the sea-coast forts or batteries are under the navy, and the same is the case in Italy.

The mutual consideration of the question of the attack and defense of a port, and the preparation of a programme and rules to be observed during the operations at Milford Haven, by a mixed board of navy and army officers is much to be commended and should be imitated. Such a plan is the best to test the efficiency of a harbor's defenses, and to indicate and illustrate the tactics to be observed by a fleet.

X.

BRITISH ADMIRALTY ANCHOR TRIALS AT THE PORTSMOUTH DOCKYARD.

The modern system of naval construction has necessitated an alteration in the form of anchor formerly in use in the Royal Navy, and this has led to a number of modified, improved, and new anchors being brought to the notice of the Admiralty and the general public. As each inventor claimed superiority, it was considered advisable by the admiralty authorities to determine the respective merits of the various types produced. With this object a series of exhaustive trials was undertaken at Portsmouth dockyard, in order that some definite conclusion might be arrived at. The experiments were carried out under the able superintendence of the captain of the steam reserve, the staff captain of the yard, and the chief constructor of the yard. The method of procedure was as follows:

SHORE TRIALS.

An ordinary admiralty pattern anchor of 49 cwt., total weight, was placed on the beach, and a distance of 30 fathoms having been measured off in a straight line, the anchor to be tried was placed at the other end of this line. A flagstaff was erected at each end of the line in order to mark the original position of each anchor. These two anchors were connected to each other by means of blocks and tackle, and a leading part from each block was taken to a powerful steam winch. In this way an equal strain would be put on both anchors, and the one that had superior holding power would remain stationary, while the other would be dragged; or if both dragged the better of the two would travel the less distance. The following anchors were submitted for trial:

Name.	Weight.		
	cwt.	*qrs.*	*lbs.*
Baxter	42	1	14
Tyzack (1)	39	1	14
Inglefield and Lenox	45	3	14
Barton's Martin	61	0	0
Wasteney Smith	48	0	4
Tyzack (2)	40	0	0

The admiralty anchor was, as stated, 49 cwt.

The accompanying diagram (1) shows the results of these trials very clearly, the distance each anchor was dragged being indicated by the black-ink line. It will be noticed that all the anchors tested were of less weight than the admiralty standard, excepting the Barton's Martin anchor, which was 24½ per cent. in excess. This gave it so great an advantage that the trial could only end in one way, for it is evident that had a 61 cwt. admiralty pattern anchor been opposed to a 49 cwt. Martin anchor, the latter must inevitably have been dragged home. With regard to the other types tested, the admiralty pattern unquestionably proved superior to all, with the notable exception of the Inglefield and Lenox anchor.

SUMMARY OF BEHAVIOR OF ANCHORS UNDER TRIAL.

The Baxter anchor dragged 17 feet and then broke ground and turned over. It then dragged 64 feet, altogether failing to take the ground for that distance. After this it took the ground, but only held for 7 feet when it once more turned over and continued to drag to the end of the trial.

The Tyzack anchor (1) on its first trial did not take the ground at all, but dragged over the surface the whole way.

The Inglefield and Lenox anchor took the ground at once and held throughout, the admiralty anchor being ploughed through the ground towards it until the end of the trial.

The Barton's Martin anchor also held, the admiralty anchor being dragged towards it; but, as before pointed out, any ordinary anchor ot 61 cwt. would have dragged one of only 49 cwt.

The Wasteney Smith anchor failed to take the ground for a considerable distance; the flukes were then forced into the ground by men, after which it dragged slowly for a short distance, then turned up sideways and dragged to the end of the trial.

The Tyzack anchor (2) having undergone some alteration by the maker, which increased the weight to 40 cwt., was tried a second time with results but little better than those first obtained.

SEA TRIALS.

Sea trials of the same anchors were subsequently carried out in the Solent; the anchors were let go in turn in 3 to 4 fathoms of water, about 45 fathoms of chain being paid out. The engines of the tug employed for the trials were then reversed so as to cause the anchor to drag. The engines were set to 12, 20, and 25 revolutions per minute, the time at which they kept going at each of these speeds being three minutes. A trial was made first in a direct line in which the anchor fell, second at 8 points away, and third at 16 points away.

The distance dragged by each anchor was recorded by two mark buoys, one attached to the anchor, the other being moored where the anchor fell. See diagram (2) in which the position of the moored buoy is shown by the + on the "Let go" line.

SUMMARY OF RESULTS.

The positions of the anchors were reported by a diver.

Baxter anchor (tried in slack tide), 42 cwt. 1 qr. 14 pounds.

Let go.................Reported lying flat on ground.
First.................At 20 revolutions dragged 53½ fathoms.
Second...............At 20 revolutions commenced dragging.
Third .... { At 12 revolutions dragged slowly.
At 20 revolutions held a short time, then failed.

Reported on surface, not holding, appeared to have turned over as at shore trial.

Tyzack anchor (with and against tide), 39 cwt 1 qr. 14 pounds.

Let go............Reported lying on side.
First.............At 20 revolutions dragged 37½ fathoms, reported embedded.
Second............At 20 revolutions continued dragging.
Third.............At 20 revolutions continued dragging

Reported to have dragged along surface for some distance and then through the ground.

Barton's Martin anchor (tried in slack tide), 61 cwt

Let go............Reported flat on ground.
First.............At 20 revolutions dragged 17¾ fathoms.
Second............At 20 revolutions holding.
Third.............At 25 revolutions dragged 27½ fathoms.

Reported well in ground.

Inglefield and Lenox anchor (tried with and against tide), 45 cwt., 3 qrs., 14 lbs.

Let go............Reported lying with arms up.
First.............At 20 revolutions dragged 14⅔ fathoms.

Reported in good position and well embedded.

Second............At 20 revolutions holding well ; no drag.
Third.............At 25 revolutions holding well; no measurable drag.

Reported buried in ground.

Wasteney Smith anchor (tried in slack tide), 48 cwt., 0 qrs., 4 lbs.

Let go............Reported to have entered ground sideways and arms up.
First.............At 25 revolutions dragged 33½ fathoms in 1½ minutes.

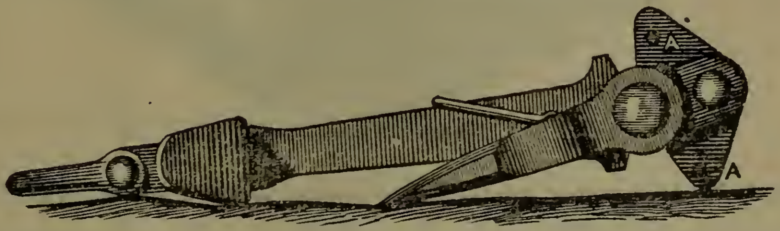
Reported arms still upward; anchor not holding. Cable shortened to 25 fathoms, to try to make flukes take the ground. At 20 revolutions dragged 28½ fathoms. Reported shank slightly lifted; arms in plane with shank; not holding.

Third............At 25 revolutions holding.

Reported well in ground.

NOTE.—This report substantially represents the relative results of the trials of the respective anchors, but does not profess to be fractionally correct.

THE INGLEFIELD AND LENOX PATENT DOUBLE-HOLDING ANCHOR.



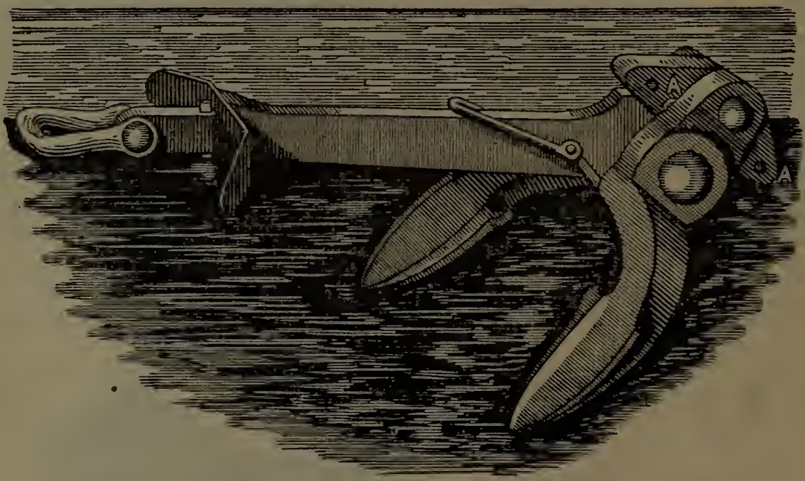
PRIOR TO A STRAIN BEING BROUGHT ON THE CABLE.

This anchor was invented with the special object of supplying all descriptions of vessels, but more especially war vessels, with an anchor on the "two arm holding" principle, which may be relied upon for quick and efficient holding at both long and short scope of cable in all kinds of anchorage.

The great improvement in this anchor lies in the construction and position of the canting or tipping piece (A). This is placed beyond, instead of under, the head of the anchor, consequently the anchor cannot rest upon it, but it depresses the arms, bringing them into position to take the ground, not only by their own weight (which alone frequently fails), but by the whole weight of the anchor.

Should the anchor be let go in soft ground, into which it would sink rapidly, leaving the arms or flukes in an upward position, as soon as a strain came on the cable it would be imparted to the shank, the first movement of which would cause the arms to fall and take firm hold of the ground. This may clearly be seen by the construction of the anchor, as shown above.

Hitherto the horns (or canting piece) of anchors constructed to hold with both arms have been centred on the turning point of the arms, so that when the arms are up the horns are directly under the heaviest part of the anchor, and are effectually retained there by the weight of the anchor resting on them. Officers who have had experience with such anchors are well aware that the only way to endeavor to get the arms down is to shorten cable until the anchor shank is lifted; this often increases the difficulty by throwing more weight on the head of the anchor. For these reasons the late Mr. Martin altogether dispensed with the horns or movable head originally patented in 1859, and his anchor then came into more general use, although it is still considered somewhat unreliable. Of late a similar head has again been patented, in connection with the Martin anchor.



WHEN HOLDING.

The principle embodied in the Inglefield and Lenox patent entirely obviates the great danger of the arms failing to take the ground. This was fully demonstrated at the recent trials at Portsmouth, England, at which the Inglefield and Lenox anchor of less than 46 hundredweight proved the best, although competing against an anchor of 30 per cent. greater weight.

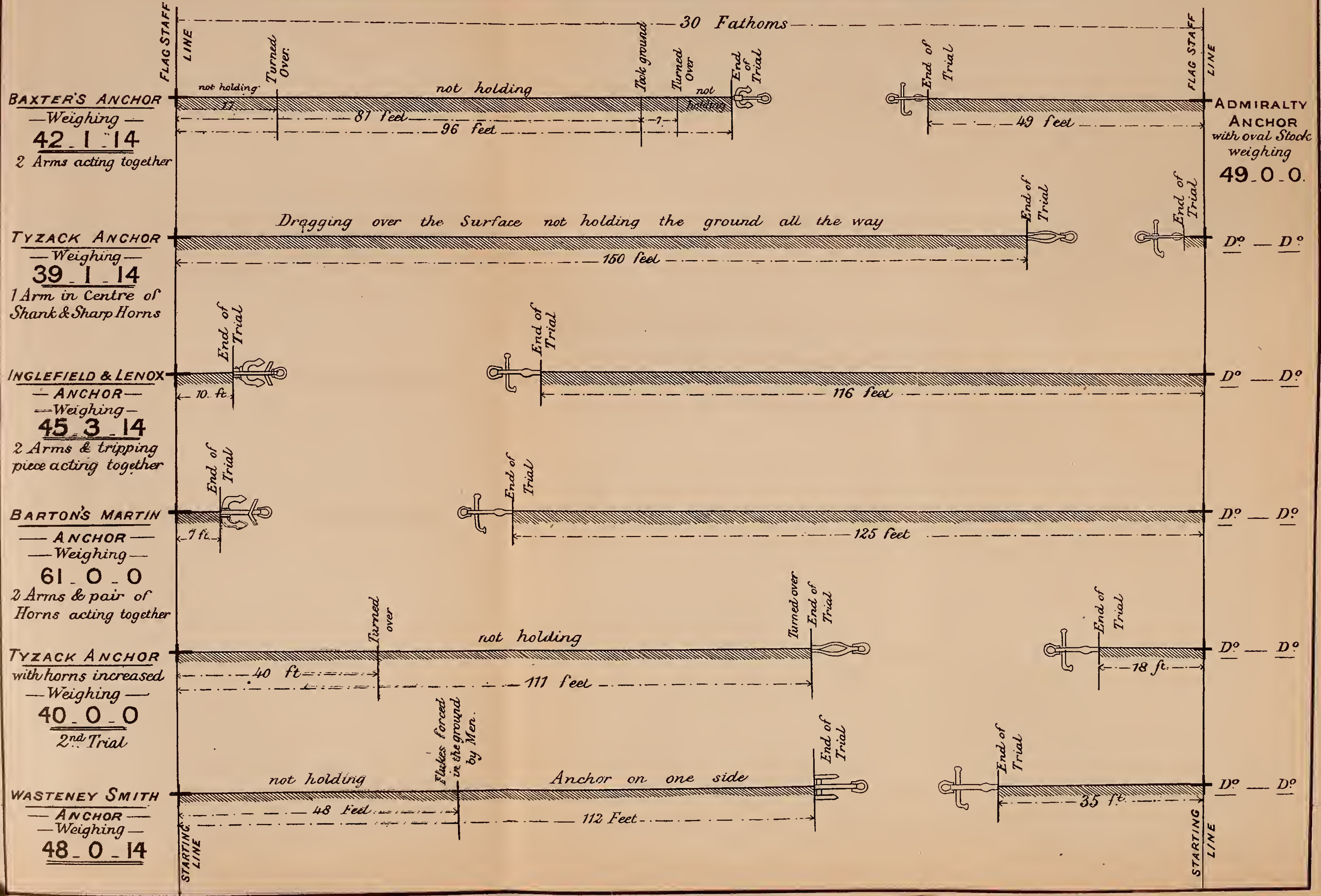
The Inglefield and Lenox anchor retains all the merits of the "two-armed holding anchors," such as stowing flat on vessels' bows, clearing the prows of iron-clad rams, and impossibility of fouling cable, &c., besides having the great advantage of certain holding, and of comparatively cheap construction. It can be used without a stock so as to draw up the hawse hole if desired.

The English Admiralty have approved this anchor for use in the naval service.

(1.)

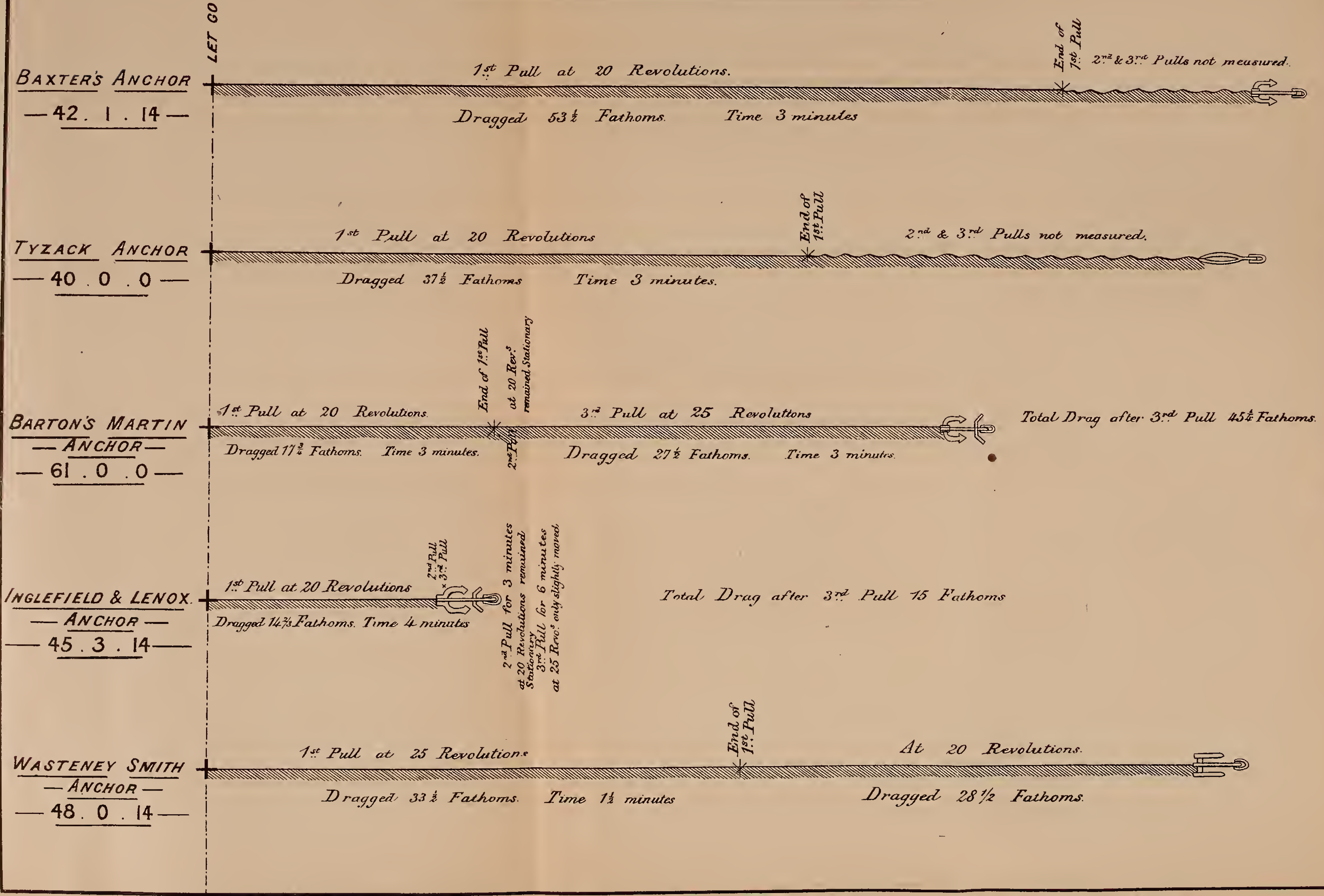
COMPETITIVE TRIALS — OF — PATENT ANCHORS — ON — FORESHORE.

AGAINST AN ADMIRALTY PATTERN ANCHOR 49 CWT. AT. H.M. DOCKYARD, PORTSMOUTH.



(2.)

COMPETITIVE TRIALS OF PATENT ANCHORS AT SEA.



Note—For Competitive merit—Observe—Weight of Anchor—distance dragged, Number of Revolutions & time.

NOTES

ON

SHIPS, MACHINERY, ORDNANCE, ARMOR, TORPEDOES, TORPEDO-BOATS, AND OTHER SUBJECTS OF PROFESSIONAL INTEREST.

SHIPS.

UNITED STATES.

VESSELS LAID DOWN.

BALTIMORE.

This twin-screw, steel, protected cruiser is building at the yard of William Cramp & Sons, Philadelphia, where her keel was laid May 5, 1887.

She is a high freeboard vessel, with long forecastle and poop-deck, a strong ram bow, and a round stern, covering and protecting the rudder, which is placed well below the water-line. There will be two smoke-pipes, and two masts fitted with military tops. The stem, stern-post, rudder, and shaft-tubes and struts are steel castings; the rest of the ship is built of rolled or wrought steel. There is a complete double bottom numerously subdivided, each compartment of which has its suction connection with a steam-pump. The engine and boiler space is completely surrounded and protected by coal in bunkers. All the bunker bulkheads, together with the main transverse and longitudinal bulkheads, are water tight, and all openings in them are fitted with water-tight doors or covers, thus dividing the ship into many water-tight compartments, each of which is directly connected with powerful steam pumps.

The outside plating of the hull is 7/16 to ½ inch thick; the inner bottom plating ¼ to 5/16 inch thick; the shear strakes, ⅝ to ¾ inch thick; the transverse bulkheads below the protective deck, 5/16 inch thick; the wing-passage bulkheads, all subordinate divisional and bunker bulkheads, ¼ inch thick; the ceiling on berth-deck and under poop 1/16 inch thick; and the coffer-dam casings surrounding the hatches on berth-deck are 3/16 inch thick.

In addition to the coal protection there is a complete protective deck, laid in two thicknesses of steel plates. The crown or horizontal part of this deck is slightly above the W. L. at normal draught, and the plates of which it is built are each 1¼ inches thick; the thickness at the knuckle, or place where the crown is joined to the inclined sides, is 3½ inches; and on the sides, which slope to 6 feet below the W. L., it is 4 inches in two plates of 2 inches each.

The engine hatches and all other openings through this deck are fitted with plate covers of the same thickness as the deck. The smoke-pipe hatches are fitted with glacis plates and armor bars.

The conning tower on the after end of the forecastle is built of 3-inch steel; and all the guns are fitted with deflective steel shields.

The armament will consist of four 8-inch B. L., mounted on either side of the poop and forecastle on slightly sponsoned platforms at a height, respectively, of 26½ and 28 feet above the W. L.; six 6-inch B. L. will be mounted 18 feet above the W. L. in broadside on the spar-deck, on sponsoned platforms, which allow of a train of 155° from the line of the keel for the forward and after pairs, and an extreme train of 130° for the guns in the waist. The secondary battery will consist of six 6-pounder R. F. G.,* six H. R. C.,† and four Gatlings.

The torpedo armament has not been decided upon, but five above-water discharging tubes will be fitted; two fixed on either side of the stem, to fire directly ahead one fixed to fire astern, and one on each bow with a train of 45°.

---

* Rapid Fire Guns.

† Hotchkiss Revolving Cannon.

All the conveniences of side-coaling chutes, steam-winches, steam-windlass, and steam-steerers, will be fitted; the latter to be operated by levers from either the conning tower or the wooden pilot-house, which is abaft the tower. An electric-light plant for about 400 lamps of 8 to 32 candle-power will be fitted.

The principal dimensions of the ship are: Length over all, 335 feet; length b. p., 315 feet; breadth molded, 48 feet 6 inches; mean draught, 19 feet 6 inches; displacement at normal mean draught, 4,400 tons.

The maximum speed, estimated to be developed over the measured mile at the above draught and displacement, is 20 knots with forced draft, and over 17 knots with natural draft.

The motive power consists of two sets of horizontal triple-expansion engines, estimated to develop 10,750 I. H. P. with forced draught. Steam will be furnished by eight double-ended cylindrical boilers, in two sets, of four each.

The coal supply at normal draught is 400 tons, but the bunker capacity is 900 tons. With the latter supply the ship has an endurance of about 3,400 knots at full speed, natural draft, and of about 12,000 knots at 10 knots speed.

CHARLESTON.

An all steel, twin-screw, cruiser of the central superstructure type, building at San Francisco, at the Union Iron Works; given to contract in January, 1887.

The ship is a reproduction of the justly celebrated Japanese cruiser Nauiwa-Kan, which has realized the greatest speed over the measured mile yet attained by any vessel of her size or class in the world.

The stem, stern-post, rudder, shaft-tubes, and brackets are of cast steel; all the remainder of the vessel is rolled or wrought steel. The plating is of the same thickness as in the Baltimore.

The coal protection is as complete as in the Baltimore; the double bottom and water-tight compartments have the same general arrangement, and the drainage system is as complete.

The protective deck is complete, and curves from the point of the ram to the extremity of the stern. It is laid in two courses of 1-inch plates on the horizontal and 1½-inch plates on the inclined sides, giving a total thickness of 2 and 3 inches, respectively.

The conning tower is on the forward bridge, and is 2 inches thick on the sides, with a ¾-inch top. The loading stations for the 10-inch guns are built of 2-inch steel and the segmental shields for the 6-inch guns are of the same thickness.

Underneath the forward bridge is the chart and wheel house, built of $\frac{5}{16}$-inch steel. The steering gear is hydraulic, and can be worked from either the chart-house or the conning tower.

The openings in the protective deck are protected as in the Baltimore, and the same arrangement of coffer-dams is fitted. The conveniences of side coaling chutes, steam windlass and winches, and electric lighting are similar in both vessels.

The armament will be two 10-inch B. L., mounted on the fore-and-aft midship line, one forward and one aft. The weight is supported beneath the deck by tubes 10 feet in diameter, built of ⅜-inch steel plates. No bulwarks are fitted to the deck at the extremities of the vessel, to admit of clear fire from these guns. Six 6-inch B. L. are mounted on the same deck, three on each broadside, on slightly projecting sponsons, and with deeply recessed bulwarks to admit of increased train.

The high bulwarks which occupy the waist are terminated by thwartship wing bulkheads, in rear of the 10-inch pivot guns, to protect the broadside battery from the blast of the guns, and also to increase the comfort and safety of the vessel in a sea way. The secondary battery will be four 6-pounder R. F. G., six H. R. C., and four Gatlings. Four above-water torpedo tubes will be fitted, but the number and type of torpedoes is yet undetermined. The two masts are fitted with a fore-and-aft rig, and each carries a military top.

The motive power consists of two sets of horizontal 2-cylinder compound engines, estimated to develop 7,500 I. H. P., and a speed of 19 knots with forced draft. The Naniwa at load draught, developed 7,650 I. H. P., and a speed of 18.9 knots, a mean of two runs over a course 9.6 knots long.

The principal dimensions are: Length over all, 320 feet; length on L. W. L., 300 feet; beam, molded, amidships, 46 feet; mean draught, with 350 tons of coal on board, 18 feet 6 inches; displacement at that draught, 3,730 tons. Total coal capacity of the bunkers, 800 tons.

NEWARK.

An all-steel, twin-screw, bark-rigged, protected cruiser, authorized, but not yet commenced.

Her principal dimensions are: Length on L. W. L., 310 feet; beam extreme, 49 feet 1¾ inches; normal draught, forward, 17 feet; aft, 20 feet 6 inches; displacement at this draught, 4,083 tons.

The bow is ram-shaped, and is strongly braced and supported by the protective deck. The stern is of the ordinary elliptical shape, but the rudder is situated well underneath the water, and forward of the overhang. The sail area is 9,586 square feet. The fore and main masts are fitted with military tops.

The stem and stern-post will be cast-steel, each in two pieces; the rudder and shaft tubes and struts are also of cast-steel. The inner bottom plating is made continuous with the bottoms of the ammunition rooms, &c., and, together with the platforms in the bow and stern, they form a complete double bottom, which is carefully made water-tight throughout its length, and is minutely subdivided. This bottom is 3 feet 3 inches deep amidships for a length of 129 feet under the machinery space. Each compartment of the double bottom has suction connection with a pump. The large water-tight compartments are more numerous than in the Baltimore, owing to the greater subdivision of the bunker space. All bulkheads are made water-tight, and are fitted with water-tight doors or covers to all openings. Each compartment has individual connection with a powerful pump. The outside bottom plating is $\frac{7}{16}$ to ½ inch thick; the inner bottom plating, ¼ to $\frac{5}{16}$ inch thick; the sides below the spar deck, ⅜ inch thick; above the spar deck, ¼ to ⅜ inch thick. An additional inside shear strake will be worked for about three-fourths of the ship's length, as also a doubling strake along the water-line for about the same distance. The transverse water-tight bulkheads are ¼ to ⅜ inch thick below the protective deck. All bunker bulkheads and transverse bulkheads above the protective deck are ⅜ inch thick. The water-tight platforms in bow and stern, connecting with the inner bottom plating, are ½ inch and ¼ inch thick, respectively. The coffer-dam casings of engine and fire-room hatches extend to 6 inches above the berth-deck, and are ¼ to $\frac{5}{16}$ inch thick. All other hatches leading below the protective deck are fitted with coffer-dams $\frac{3}{16}$ inch thick.

The steel protective deck is complete, and curves longitudinally from the point of the ram to the extremity of the stern, where it covers the steering gear. The horizontal crown is about 1 foot above the water-line, the sides sloping to about 5 feet below. The deck is laid in two courses, the first being complete and ½ inch thick, the second being of 2½-inch plates on the inclined sides and 1½-inch plates on the horizontal, increased to 2 inches over the steering gear.

The conning tower on the forward bridge, abaft the forecastle, is 8 feet 6 inches in diameter, and built of 3-inch steel plates. The top is 1½ inches thick. A steel communicating tube, 12 inches in diameter and 2½ inches thick, extends in one length from the protective deck into the conning tower, to carry speaking tubes, steering gear, signal wires, &c.

All the guns are to be fitted with segmental steel shields.

The armament will consist of twelve 6-inch B. L., so mounted that there is direct bow and stern fire from four guns, and beam fire from six guns. The guns are all mounted on the spar-deck, at a mean height of 16 feet 6 inches above the water-line. The bows and quarters are cut away to admit of fire ahead and astern from the forward and after pairs of guns, which are mounted on platforms slightly sponsoned out from the ship's sides; the neighboring pairs are also mounted on sponsons, but with projection sufficient to give them bow and stern fire clear of the forward and after pairs. The two pairs of guns in the waist are slightly sponsoned, but have the bulwarks deeply recessed at the ports, admitting of a train of 140°. The secondary battery will be four 6-pounder R. F. G., four H. R. C., and four Gatlings. The torpedo armament is undetermined, but arrangements are made for six above-water discharging tubes, all having a train of 90°, one being on each bow, one on each quarter, and one on each side in the waist.

The motive power will consist of two sets of horizontal triple expansion engines, estimated to develop 8,500 I. H. P. and a speed of about 18 knots.

The complement of men is placed at 300.

The capacity of the bunkers is 850 tons, which will enable the ship to steam about 3,100 knots at full natural draft speed, or 10,700 knots at 10 knots speed.

"GUNBOAT NO. 1."

An all steel, twin-screw vessel, very similar in general design to the "torpedo cruiser" class of the British navy, of which the Archer is the type. She is being built at Philadelphia, at the yard of William Cramp & Sons, where her keel was laid May 14, 1887.

She has a high freeboard, long poop and forecastle decks, a strengthened ram bow, elliptical stern, the rudder placed well below the water line, and is rigged as a three-masted schooner, spreading 6,353 square feet of canvas. The stem and stern-post are of cast steel, the latter in two pieces, and the rudder is of wrought iron. The outside bottom and side plating up to the upper deck are $\frac{3}{8}$ to $\frac{7}{20}$ inch thick; above the upper deck the plating is $\frac{1}{4}$ inch, except in wake of the torpedo and gun ports, where it is 1 inch thick. An additional inside shear strake $\frac{3}{10}$ inch thick is worked for a distance of 114 feet in the waist. All bulkheads, transverse, longitudinal or bunker, are made water-tight and are $\frac{3}{16}$ to $\frac{1}{4}$ inch thick. All openings in these bulkheads are closed by water-tight doors. The inner plating of the bulwarks is $\frac{1}{8}$ inch thick, except in wake of the rigging, where it is $\frac{1}{4}$ inch. The ceiling on the berth deck and under the poop-deck is $\frac{1}{16}$ inch thick.

There is a complete curved steel $\frac{3}{8}$-inch water-tight deck, with its crown slightly above and parallel to the 14-foot water-line, and its sides three feet below the same water line. At the ends of the vessel this deck curves down to the point of the ram and the extremity of the stern, where it covers all the steering gear. All hatches in this deck may be closed by W. T. shutters or doors of the same thickness as the deck; they are also surrounded by coffer-dams extending to 18 inches above the upper deck, the casings of which are $\frac{3}{16}$-inch steel.

The coamings of the engine, boiler, and fire-room hatches extend to the height of the hammock netting, that of the forward fire-room extending to the forecastle deck, and are all built of $\frac{1}{4}$-inch plates. On the after end of the forecastle is the oval conning tower, 7½ feet athwartships by 4 feet fore and aft, and 2 inches thick; forward of it is the wooden pilot-house, and in each is fitted steam steering apparatus.

The only protection to the vital parts is the amount of coal carried in the space in wake of the machinery and boiler space. Both below and above the water-tight deck the bunkers occupy all the space within these limits, except the necessary passages and hatches, and, their bulkheads being water-tight, serve to further increase the water-tight subdivision of the ship. The under-water body of the vessel is divided into twelve main W. T. compartments by complete transverse bulkheads.

The armament will consist of six 6-inch B. L. mounted, two on the forecastle on slightly sponsoned platforms, two similarly situated on the forward end of the poop and one each side in the waist on the upper deck, all fitted with segmental steel shields. The forward and after pairs have a train of 160° from the line of the keel, and the pair in the waist may train through an arc of 140°. The secondary battery will comprise five R. F. G., two H. R. C. and one Gatling. Eight torpedo tubes will be fitted above water, and on the upper or spar deck. The tubes in the stem and in the stern are fixed to fire in the line of the keel, while those on the bow, quarter, and in the waist have a train of about 45°.

The motive power will consist of two sets of horizontal triple-expansion engines driving twin screws, estimated to develop 2,200 I. H. P. with natural draft and 3,200 with forced draft. (It is probable that this estimate will be exceeded by the contractors.)

The coal capacity is placed at 400 tons, the complement of men at 150, and the maximum speed at 17 knots.

The dimensions are: Length, b. p., 230 feet; beam, 36 feet; draught forward, 13 aft, 15 feet; displacement at this draught, 1700 tons.

"GUNBOAT NO. 2."

An all steel, single-screw vessel, building at Baltimore, at the yard of the Columbian Iron Works. Her keel is not yet laid.

Her principal dimensions are: Length, b. p., 175 feet; beam, extreme, 31 feet; depth of hold from upper deck beams, 15 feet 7 inches; mean draught, 11 feet 7 inches; displacement, 870 tons. A fair amount of sail can be carried, the barkentine rig spreading 4,853 square feet of canvas. The stem is of wrought steel; the stern-frame, rudder, and shaft tube of cast steel. The outside plating is $\frac{3}{8}$ inch thick up to and including the shear strake; above the latter the bulwark plating is 1 inch thick in wake of the 6-inch B. L. and machine guns, $\frac{3}{8}$ inch where subject to the blast of the 6-inch guns, and $\frac{1}{4}$ inch thick on the remainder. The inner plating of the bulwarks is $\frac{1}{16}$ inch thick, increased to $\frac{3}{8}$ inch in wake of the chain plates.

The hull is divided by nine transverse W. T. bulkheads, and the coal bunker bulkheads into compartments which are water-tight and which are capable of being separately flooded or drained. The collision bulkhead is $\frac{1}{4}$ inch thick, the other transverse bulkheads are $\frac{3}{20}$ to $\frac{3}{16}$ inch thick, and the bunker bulkheads are $\frac{1}{8}$ to $\frac{7}{32}$ inch thick.

All openings in these bulkheads are fitted with water-tight doors easily handled.

The engine and boiler space is surrounded and covered as completely as possible by coal in bunkers. Further protection is given to the same space by a W. T. steel deck $\frac{3}{8}$ to $\frac{5}{16}$ inch thick, which curves from a height of 8 inches above the W. L. at the crown to 2 feet 6 inches below the W. L. at the sides. All openings in this deck are made W. T., and the engine and boiler hatches, &c., are surrounded by coffer dams, which extend to 18 inches above the spar deck and are built of $\frac{3}{16}$-inch plating. Steel bars 2 inches apart, 3 inches deep, and $\frac{3}{8}$ inch thick are fitted to smoke-pipe hatches, ventilator trunks, engine hatches, and all other openings.

The armament consists of four 6-inch B. L. mounted on sponsons, two on each side at a height of 10 feet 8 inches above the W. L., and fitted with segmental steel shields. The forward pair is just abaft the break of the forecastle, the after pair just forward of the break of the poop, having clear bow and stern fire, respectively. The platforms on which these guns are to be mounted are raised about 4 feet above the level of the spar-deck. Two 6-pounder R. F. G. will be mounted, one on the forecastle and one on the poop; also two H. R. C. on the rail in the waist.

Hand steering gear only is provided, but there will be a steam windlass fitted.

The motive power consists of one set of horizontal compound engines, estimated to develop 900 I. H. P. with natural draft and 1,350 with forced draft. This latter I. H. P. is expected to develop a speed of 13 knots. Steam will be furnished by four cylindrical two-furnace steel boilers. The coal supply is placed at 160 tons, and the complement of men at 100.

THE "DYNAMITE CRUISER."

The so-called dynamite cruiser is very similar in general appearance to an enlarged torpedo-boat, having a low freeboard of but 5 feet, no bulwarks, and great length in proportion to the beam. The vessel is to be built of steel, with the exception of the stem, stern-post, and rudder, which will be of forged iron. The framing is to be very light, but 7 pounds per lineal foot, and is to be in one piece from keel to gunwale. The reverse frames are but 4 pounds per lineal foot. The outside plating is $\frac{1}{4}$ to $\frac{1}{5}$ inch thick. The flooring, 15 inches high amidships, is to be in one piece from bilge to bilge, and is $\frac{1}{4}$ inch thick. The deck plating is $\frac{3}{16}$ inch thick and is planked with white pine. Water-tight bulkheads $\frac{1}{6}$ inch thick divide the vessel into a number of compartments, each of which has its individual drainage.

A steel conning tower 1 inch thick is situated forward.

The motive power consists of two sets of triple-expansion engines, each of which drives one screw. These are estimated to jointly develop 3,200 I. H. P.

The boilers are cylindrical—four in number—and are placed in two fire-rooms fitted for using forced draft.

Steam steering and anchor gear will be fitted.

The proposed armament is three pneumatic tubes for throwing dynamite shells. These tubes are to be built into the hull of the vessel at a permanent angle of 10° with the horizon, arranged side by side in three parallel vertical planes, the muzzles projecting slightly above the deck near the bow. The only train that can be given is by the helm, the shells being thrown in the line of the keel. The range is varied by increasing or decreasing the pressure of air admitted into the tubes.

The principal dimensions of the vessel are: Length on water line, 239 feet; length over all, 246 feet; beam, extreme, 26 feet 6 inches; depth from base line to top of gunwale, 13 feet; mean draught, with 85 tons of coal on board, 8 feet; displacement at 8-foot draught, 686 tons.

The vessel is being built at Philadelphia at the yard of William Cramp & Sons. Her keel will be laid about July 1.

A speed of 20 knots on trial is required by the contract.

The following information regarding the material to be used in the construction of the vessels just described was furnished by Commander R. D. Evans, U. S. Navy, chief inspector of steel for new cruisers:

The manufacturers engaged in making material for the new cruisers are:

Phœnix Iron Company, of Phœnixville, Pa.: Shapes for cruiser Baltimore and gunboat No. 1.

Carnegie, Phipps & Co., of Pittsburgh: Plating and boiler material for cruiser Charleston, plating for cruiser Baltimore and gunboat No. 1, plating and boiler material for gunboat No. 2.

Pacific Rolling Mills, of San Francisco, Cal.: Shapes and protective-deck plate for cruiser Charleston.

Park Brothers & Co., of Pittsburgh, Pa.: Boiler material and portion of ship plate for cruiser Baltimore and gunboat No. 1.

Linden Steel Company of Pittsburgh: Protective-deck plate for cruiser Baltimore, gunboat No. 1, and gunboat No. 2.

The Pennsylvania Steel Company of Steelton, Pa., make all the steel rolled by the Phœnix Iron Company.

Carnegie, Phipps & Co., make their own steel.

The Pacific Rolling Mills make their own steel.

The steel used in the new vessels is all "open-hearth steel," and must show a tensile strength of at least 60,000 pounds per square inch of original cross-section, and an elongation in 8 inches of at least 25 per cent. The steel is also subjected to a cold bending test, requiring the test piece to bend over flat on itself without showing sign of fracture. In addition there is required a quenching test, where the test piece is heated to a cherry red, plunged into water at a temperature of 82° F., then doubled round a curve, of which the diameter is not more than one and one-half times the thickness of the piece tested, without presenting any trace of cracking. The ends of the test piece to be parallel after bending.

Boiler material (for the furnaces) ranges from 50,000 to 55,000 pounds tensile strength, with an elongation of not less than 29 per cent. in 8 inches. For other parts of the boiler the tensile strength ranges from 57,000 to 63,000 pounds, with an elongation of not less than 25 per cent. in the direction of the rolls, nor below 21 per cent. for a piece cut transversely.

The protective-deck plating ranges from ⅜ to 4 inches in thickness, and must possess a tensile strength ranging from 60,000 to 80,000 pounds per square inch with an elongation of from 25 to 19 per cent. respectively.

The stem casting for cruiser Baltimore has been made by the Standard Steel Casting Company, at Thurlow, Pa., and is probably the finest casting of the kind ever turned out of the sand. Twenty thousand pounds of material were used in the run, and the finished casting weighs upwards of 12,000 pounds. Specimens from the body of the casting give the following results: Ultimate strength, 85,000 pounds per square inch with 10 per cent. elongation in 8 inches, 48,500 pounds elastic limit. A bar 1 inch square, without any subsequent treatment in the way of annealing or tempering, was bent cold through an angle of 95° without flaw or crack.

From results so far obtained it is reasonable to conclude that American manufacturers can readily furnish all the ship materials the Government may require of the present standard quality, which is higher in some respects than that of any other Government.

STEAM TRIALS.

ATLANTA.

On April 13, 1887, this vessel left the New York navy-yard, for her full-power trials in Long Island Sound. The trials were not intended for speed trials, but merely to ascertain the maximum I. H. P. the engines could develop, and to attain if possible the maximum power of 3,500 I. H. P. required by the contract. The vessel had on board her own complement of officers and men, her battery, provisions and stores for two and a half months, and 265 tons of coal, and was drawing 14 feet 9 inches forward, 19 feet 3 inches aft, or a mean of 17 feet. The mean normal draught (as originally designed) is 16 feet 10 inches, and the full coal capacity of the ship is 500 tons. The trial was a continuous six hours' run with forced draft. Indicator cards and other data were taken at half hour intervals. The mean of the results obtained during the six hours were: Steam in boilers, 87.1 pounds; revolutions, 67.27; slip of screw, 4.44 per cent.; total I. H. P., 3,345.42, of which 352 I. H. P. was developed by the auxiliary engines; average I. H. P. developed by the main engines, 2,993.42; average speed, 15.5 knots. The maximum results obtained during the trial were, revolutions 73, total I. H. P. 3,482.69.

The auxiliary engines working during the trial were 2 air and circulating pumps, 1 auxiliary air and circulating pump, 6 blower engines for fire-room, 2 ventilation blowers, 2 flushing pumps, 1 main compartment pump, 1 dynamo engine, 2 feed pumps.

ENGLAND.

NAVAL POLICY AND VESSELS PROPOSED.

No new vessels have been commenced during the past year, but it is intended to make considerable additions to the cruising fleet during 1887-'88. It is proposed by the Admiralty to make provision for the relief of the small vessels on foreign stations during the next two years. An inquiry into the composition of the squadrons abroad made it apparent to the Admiralty that too large a proportion of the naval strength was absorbed by small vessels, which, however well adapted for police purposes in time of peace, or for operations in shoal waters or rivers in time of war, would be of comparatively little value for the protection of commerce on the high seas in time of war. Governed by these considerations, it is believed by the Admiralty that a limited number of larger and more powerful vessels, moving from place to place on a station, can be made to more efficiently perform the work of the numerous but less mobile flotilla now employed. The vessels to be built will have a speed equal to, or in excess of, any of their class elsewhere, and are intended to be a match for anything of like displacement which they might encounter.

The most notable vessels proposed to be laid down in 1887–'88 are two steel, unsheathed, 20-knot protected cruisers, to be built at the Chatham dockyard, named—

MEDEA—MEDUSA.

They are to be made suitable in all respects for independent sea service and for being driven at high speed in rough water, but will be entirely dependent upon their steam power and twin screws for propulsion. They will be fitted with fore and aft steadying sails only. The protective steel deck will be complete from stem to stern and will completely protect all boilers, engines, steering gear, magazines, &c. Above this deck the space to the next deck will be minutely subdivided. Protective coal bunkers, coffer-dams, &c., will be built as is usual in all vessels of the protected type. A double bottom on the cellular principle, adapted for water ballast, will be fitted.

The principal dimensions of these cruisers are: Length, 265 feet; beam, 41 feet; mean draught, 16 feet 6 inches; displacement, 2,800 tons. The motive power is to consist of two sets of vertical inverted triple-expansion engines, which are intended to develop a speed of not less than 20 knots over the measured mile, when fully equipped and with 400 tons of coal on board, and to maintain a sea speed of 17 to 18 knots; 9,000 I. H. P. is expected from these engines, with forced draft. The coal endurance is to be sufficient to cover 8,000 knots at a speed of 10 knots per hour. Special arrangements of armored coamings or hoods are to be fitted for the protection of the vertical cylinders. The armament will include six 6-inch B. L., in broadside, on centre pivot mountings, nine 6-pounder rapid-firing guns, a supply of machine guns, and six torpedo tubes, under cover. The bow will also be strengthened for ramming in the usual manner.

Three other cruisers are to be commenced during the same year, and named—

MELPOMENE—MARATHON—MAGICIENNE.

The first at Portsmouth dockyard, and the other two by contract. They will be similar to those just described, but will have their bottoms wood sheathed and coppered, so as to enable them to remain afloat for long periods without serious fouling of the bottom and consequent loss of speed. They are to have horizontal engines placed entirely below the protective deck.

These changes involve an increase of displacement and a slight decrease in the maximum speed, from 20 knots to 19¾ knots, which are accepted in view of the special services for which the vessels are intended.

In armament, protection, and all other qualities the conditions are the same as in the unsheathed 20-knot cruisers.

NYMPHE—DAPHNE.

Two small cruisers of the Buzzard type, described on page 195 of "No. V," are to be built, one at the Portsmouth dockyard named Nymphe, and one, named Daphne, at Sheerness. The proposed indicated horse power is increased to 2,000, which is expected to develop a speed of 15 knots over the measured mile.

PIGMY—PHEASANT—PARTRIDGE—PLOVER—PIGEON—PEACOCK.

Six cruising gun vessels of the type of the Rattler, described on pages 195 and 196 of "No. V," have been ordered, the first at Sheerness, the next two at Devonport, and the last three at Pembroke dockyards. They have 1 foot more beam than the Rattler and a displacement of 755 tons. They are 165 feet long, 30-feet beam, and have a mean draught of 11 feet 4 inches. The engines are horizontal, triple expansion, driving a single screw, and estimated to develop 1,200 I. H. P. with forced draft, and a speed of 13¾ knots. The coal supply will be 105 tons at normal draught.

Both of these two last types have a fair amount of sail power, and have wood-sheathed and coppered bottoms.

SHARPSHOOTER.

A fifth steel torpedo gunboat, similar to the Grasshopper, described on pages 87, 140, and 196 of "No. V," has been ordered at Devonport.

During the past year thirty-seven vessels of various classes have been stricken from the navy list, and either sold, or dismantled and relegated to use as hulks for various purposes. This number includes five armor-clads, seven cruisers of the third class, sixteen gun-vessels, one dispatch vessel, and eight special-service gunboats.

A table giving the present value of the British fleet has been compiled at the Admiralty on the following basis:

The first cost only of the vessel is given, and that is supposed to be paid the year the vessel was completed for service. All vessels now building or completing are supposed to be completed on March 31, 1887, the date for which the table was compiled. This is exclusive of the Nile and Trafalgar, whose completion is still remote. The first cost of all vessels, whose period of usefulness is estimated to be past, is deducted. In making this estimate the following periods from date of completion are accepted as a fair average estimate of the useful life of different classes of vessels:

For armored, protected, and partially protected iron or steel vessels, twenty-two years.

For corvettes, sloops, torpedo cruisers, gun vessels, gunboats, troop ships, and other vessels, fifteen years.

For torpedo-boats, steam launches, &c., eleven years.

For small vessels, tugs, and yard craft, eighteen years.

For guard, receiving, training, and harbor vessels, twenty-two years.

The estimated value of gun mountings, &c., is deducted, as their cost is a separate appropriation.

Subject to these considerations the following table is prepared:

Armored, protected, and partially protected iron or steel ships at present on the strength of the navy, at first cost		$94,492,830
Cost of new ships not yet complete (actual and estimate)		41,306,850
		135,799,680
Cost of ships completed prior to 1865–'66	$1,839,540	
Estimated value of gun mountings, &c	6,326,450	
		8,165,990
Net total cost of armored, &c., ships at normal strength		127,633,690
Corvettes, sloops, &c., at present in strength of the Navy, at first cost		35,943,970
Cost of new ships not yet complete (actual and estimate)		5,012,500
		40,956,470

Cost of ships completed prior to 1872–'73	7,650,140	
Estimated value of gun mountings, &c	973,300	
		8,623,440
Net total cost of corvettes, &c., at normal strength		32,333,030
Torpedo-boats, steam launches, &c., at present on strength of Navy, at estimated first cost		7,299,750
Small vessels, tugs, tanks, &c., at present in the service, at first cost		2,180,190
Cost of vessels completed prior to 1869–'70		983,030
Net total cost of small vessels, tugs, &c		1,197,160
Receiving, training, guard, and harbor ships, &c., at present in the service, at first cost		15,913,450
Cost of vessels completed prior to 1865–'66		14,421,440
Net total cost of receiving, training, guard, and harbor ships built since 1865–'66		1,492,010
First cost of vessels completed since the periods referred to for the several classes, which are at present laid up as obsolete, or for sale; also, of ships completed within those periods which have been sold, lost, or otherwise disposed of		21,613,070
Grand total net cost of vessels necessary to maintain the fleet at normal strength		$191,568,720

In order to approximate to the wastage or depreciation of the fleet so as to afford reliable data upon which to predicate the extent of ship-building requisite in each year to maintain the fleet at its present authorized strength, a certain yearly percentage for deterioration on the cost value as assigned by the last table must be allowed. In establishing this percentage the useful lifetime of the different classes as before given is considered as a basis. In addition, allowance is made for the value remaining in the vessel after the expiration of the given number of years of her probable life. In order to carry out the principle advocated, the realized value, if the vessel is sold, must be credited to the navy appropriation.

The percentage of deterioration allowed is for:

	Per cent.
1. Armored, protected, and partially protected iron and steel vessels	4
2. Corvettes, sloops, torpedo cruisers, gun vessels, gunboats, and troop ships	6
3. Torpedo-boats, steam launches, &c	9
4. Small vessels, tugs, and yard craft	5
5. Guard, receiving, training, and harbor vessels	4
6. Vessels completed within the periods referred to for the several classes, but which are obsolete, lost, sold, &c	4½

With these percentages allowed, and the calculated values obtained in the previous table, the following result is arrived at:

1. Armored, &c., ships	4 per cent. of	$127,633,690 =	$5,105,350
2. Corvettes, sloops, &c	6 per cent. of	32,333,030 =	1,938,980
3. Torpedo-boats, &c	9 per cent. of	7,299,750 =	656,980
4. Small vessels, &c	5 per cent. of	1,197,160 =	59,860
5. Guard vessels, &c	4 per cent. of	1,492,010 =	59,680
6. Obsolete, lost, sold, &c	4½ per cent. of	21,613,070 =	972,590
Total		191,568,710 =	8,793,440

From the preceding calculations and estimates it thus becomes apparent that in order to maintain at its normal strength a fleet whose present actual value, for war purposes, is $191,568,710, the annual expenditure for ship-building, exclusive of the ordnance expenditures, should be $8,793,440.

IMPÉRIEUSE—WARSPITE.

These armored vessels, described on pages 74, 198, and 199 of "No. V," may be considered practically failures for service as originally designed. Owing to the increased weights of the guns, machinery, shields, &c., that have been put in the vessels since their original design, they have been found to draw, when fully equipped for sea and the full coal capacity on board, nearly 3 feet more water than was intended. It is but fair to state that the original design contemplated but 400 tons of coal on board when the ships were at normal draught, but as the coal capacity was afterwards fixed at 1,200 tons, allowance of armored free-board should have been made for the increased amount.

The armored freeboard was intended to be 3 feet 3 inches when the vessels were at their normal mean draught of 25 feet. The increased weight of armament, machinery, &c., increased the draught 11½ inches, reducing this freeboard to 2 feet 3½ inches. With the full bunker capacity (900 tons) on board the draught was still further increased 14 inches, leaving the armored freeboard but 1 foot 1½ inches, and with the full coal capacity on board the top of the armor belt would be very nearly flush with the water. As four of the torpedo tubes are above water, and have ports cut through the armor belt, this decrease of freeboard rendered them useless, it having been shown during an experimental cruise of the Impérieuse in December, 1886, with but 800 tons of coal on board and in a calm sea, that in attempting to discharge the broadside torpedoes, they jammed in the tubes and altered shape to a dangerous degree. In order to render them of any use they will have to be restored to their intended height above the water-line. It is believed that this can be accomplished by removing part of the superstructure and dispensing with all top hamper and its attendant supply of stores, equipments, &c., and limiting the maximum coal supply to the bunker capacity of 900 tons. The masts are accordingly being removed from both vessels, leaving them but one signal mast stepped between the funnels and fitted with a military top. The actual draught of the ship on the cruise mentioned, with 850 tons of coal, was 26 feet 6 inches forward, 27 feet 6 inches aft, the designed normal draught being 24 feet 6 inches and 25 feet 6 inches.

However faulty the vessels may be, their engine-power has more than realized the expectations of the builders.

In May, 1886, the Warspite, when very light, drawing but 22 feet forward, 24 feet 11 inches aft, developed 7,451 I. H. P. with natural draft, and a speed of 15¼ knots, on a consumption of 2.69 pounds of coal per hour per I. H. P. With forced draft 10,242 I. H. P. was developed, and a speed of 17¼ knots on a consumption of 2.9 pounds of coal per I. H. P. per hour, the steam pressure being 92.6; vacuum, 28.1; revolutions, 87.3; pressure in cylinders, starboard, 46.14 and 13.99; port, 47.9 and 13.73.

The official trials of the Impérieuse are given on page 198 of "No. V," but on September 1, 1886, with all guns and stores on board and 900 tons of coal in the bunkers, drawing 25 feet 11 inches forward, 27 feet 6½ inches aft, she developed a mean speed of 16 knots, with 89 revolutions of the engines, and a vacuum of 28 inches in the condenser.

The engines of both these vessels were originally designed to develop 7,500 I. H. P. with natural draft.

VESSELS LAUNCHED.

Since the publication of "General Information, Series No. V," the following vessels have been launched:

VICTORIA.

Partially described on page 111, of "No. IV," and pp. 42, 43 of "No. V," under the name Renown, the name having been changed when the ship was launched, April 9,

1887. The keel was laid at Elswick, April 23, 1885, since which time some changes have been made in the details of the original design.

The I. H. P. with forced draft has been increased to 12,000, which it is expected will develop a speed of 16.75 knots when the ship is at normal draught, carrying 1,180 tons of coal.

The armament will include one 10-inch, 26 ton, B. L., in place of the 9.2-inch, 18 ton, B. L. originally designed. Twenty-one rapid-firing guns, 6-pounders and 3-pounders, will be included in the secondary battery.

The Victoria has been built and engined, and will be armed, by the Elswick firm.

SANS PAREIL.

A sister ship in every respect to the Victoria, was launched May 9, 1887, by the Thames Iron Company at Blackwell, where her hull was laid April 21, 1885.

ORLANDO—UNDAUNTED—AUSTRALIA—NARCISSUS—GALATEA—IMMORTALITÉ.

Belted cruisers described on page 112 of "No. IV," and page 79 of "No. V." They were laid down the last week of April, 1885, and were launched respectively, August 3, 1886; November 27, 1886; November 27, 1886; December 22, 1886; March 10, 1887; June 7, 1887.

These vessels, like the Impérieuse and Warspite, are found to draw much more water than they were originally designed for; and for very similar reasons.

They were designed in 1881 and were intended, with all their legend weights on board, to have a mean draught of 21 feet, and to carry 18 inches of the 5 feet 6 inch belt above the water. Although the bunkers of the ships were constructed to carry 900 tons of coal, the weights referred to included but 500 tons, it having been calculated that this amount would carry them about 4,500 knots, at 11 knots an hour, which was apparently satisfactory to the Board of Admiralty.

After the contracts to build the vessels had been assigned, it was decided to change the engines from compound of 7,500 I. H. P. to triple-expansion of 8,500 I. H. P.

The weight of the 9.2-inch guns was increased from 18 tons to 22 tons, the number of R. F. G. was increased from six to sixteen, and the complements of men were increased.

These changes added 186 tons to the displacement, and increased the draught by 7 inches, placing the top of the belt but 11 inches above the water-line.

It has now been decided that the entire coal capacity of 900 tons shall be carried to sea, which will further increase the draught 18 inches, and place the top of the belt about 6 inches below the water-line when the ship is ready for sea. Their cost complete for sea is about $1,525,000 each.

The statements concerning excessive displacement and increased draught of these vessels, as also of the Impérieuse and Warspite, are taken from the official report of the First Lord of the Admiralty.

FORTH.

This protected cruiser, the last of the Mersey type described on page 196 of "No. V," was launched October 23, 1886.

BUZZARD.

A small, unprotected, composite, 14 knot cruiser described on p. 194 of "No. V," was launched May 10, 1887, at Sheerness dockyard, where her keel was laid May 1, 1886.

RATTLER—WASP—LIZARD—BRAMBLE.

Gun vessels partially described on pages 195 and 196 of "No. V," were launched during the year, the first in August, 1886, and the last on December 11, 1886. The displacement of these vessels has been increased to 715 tons, at normal mean draft of 11 feet 2 inches, with 105 tons of coal on board. Their length is 165 feet, and beam 29 feet.

COSSACK—PORPOISE—TARTAR—SERPENT.

Cruisers of the Archer class, described on pages 85, 86, 139, and 196 of "No. V," were launched on June 3, 1886, May 5, 1886, October 24, 1886, and March 10, 1887, respectively.

RATTLESNAKE.

The unnamed torpedo gun-boat of the Grasshopper class, described on pages 87, 140, and 198 of "No. V," was launched at Birkenhead, from the yard of the Messrs. Laird, on September 11, 1886.

STEAM TRIALS.

BENBOW.

This vessel is described on page 111 of "No. IV," and pages 41, 42, "No. V." The steam trial took place in October, 1886, the engines being in charge of their contractors, Messrs. Maudslay, Sons, & Co. The trial with natural draft took place October 28, off Sheerness, the course being from the Nore to the North Foreland, and the weather being very favorable. This trial was of four hours' duration, during which time the engines worked smoothly, and there were no signs of priming in the boilers. The mean results were: Pressure at engines 86 pounds; vacuum starboard 25.5, port 24.8; revolutions, starboard 95.14, port 96.34; pressure in cylinders, starboard 46.84 and 11.49, port 43.63 and 12.43; total I. H. P. 8,614 (the contract requiring only 7,500 I. H. P.); speed 16.3 knots. The draught of the vessel was 22 feet 3 inches forward and 24 feet 6 inches aft; the normal load draught being 26 feet 3 inches forward and 27 feet 3 inches aft.

On October 30 the engines were tried with forced draft; the course, as before, being off Sheerness, and the duration four hours. The trial proceeded to its close without mishap or interruption, the engines working smoothly and the boilers giving an ample supply of steam without any tendency to priming. The mean results were: Pressure at engines, 89.6; vacuum, starboard 28.4, port 27.1; revolutions, starboard 100.99, port 102.44; total I. H. P. 10,852.63 (the I. H. P. required being 9,500); speed 17.5 knots. The draught of the ship was practically the same as before.

At the conclusion of the four hours' trial a trial was made with the centrifugals stopped and the condensers used as a jet condenser, which proved satisfactory.

This vessel is completing and being got ready for commission at Chatham dockyard. The estimated cost complete for sea is about $4,200,000.

CAMPERDOWN.

Described on pages 41, 42, and 196 of "No. V," was taken outside of Spithead on March 7, 1887, for her preliminary steam trials. The ship was drawing 23 feet forward 24 feet aft (normal draught 26 feet 3 inches and 27 feet 3 inches). Three runs were made over the measured mile, the first two with natural draft developing a mean of 8,110 I. H. P. and 15.7 knots speed, with 96.5 revolutions. The third run was with forced draft, and developed 9,150 I. H. P. and 17.2 knots speed.

On March 14, 1887, the contractors' trials took place, the draught being 22 feet 3 inches forward, 24 feet 5 inches aft. The results obtained on one run over the measured mile with natural draft were: Steam in boilers 82.3; vacuum, starboard 28.33, port 28.29; revolutions 94.4 and 95.4; I. H. P. 8,606; speed 16.3 knots.

A similar run was then made with forced draft, when 11,741 I. H. P. and 17.144 knots speed were developed. The estimated I. H. P. was 7,500 with natural draft, and 9,500 with forced.

A continuous run was then made for four hours in the Channel without any mishaps.

In all of these trials the engines are reported to have worked with remarkable smoothness, with no heating of bearings nor priming of boilers. The ventilation is also said to have been exceptionally good.

ANSON.

This powerful battle-ship—described on pages 41, 42, and 196 of "No. V"—was taken outside of Portsmouth April 4, 1887, for the first of her steam trials. The ship was light, drawing but 22 feet 6 inches forward, 24 feet 2 inches aft (normal draught, 26 feet 3 inches and 27 feet 3 inches), and was first tried with natural draft over the measured mile. The results of the two runs were: Pressure in boilers 94.43; vacuum, starboard 29.31 and 21.18, port 27.9 and 27.26; pressure in cylinders. starboard 40.08 and 10.71, port 47.41 and 11.24; revolutions, 95.2 and 98.7; total I. H. P. 8,319 (the estimate being 7,500 I. H. P.); speed 16.5 knots; coal consumption, 2.4 pounds per I. H. P. per hour.

Four hours continuous steaming developed an average speed of 17.6 knots per hour, by patent log.

After this trial a preliminary forced-draft trial was had for half an hour, when the engines worked up to 110 revolutions, and developed a mean collective I. H. P. of 12,543 (the estimate being 9,500 I. H. P.). The engines worked smoothly and satisfactorily throughout all the trials.

Some turning trials were made with the results that a complete circle of 1,920 feet diameter was made in 5 minutes and 15 seconds, with helm hard a-starboard, and in 5 minutes and 47 seconds, diameter 1,950 feet, with helm hard a-port. The helm was shifted in 27 seconds from 34½° starboard to 34½° port.

On April 6, the ship being at the same mean draught as on the 4th, the contractors' forced-draft trials were had at the same place.

The mean of several runs over the measured mile gave 12,568 I. H. P, and 17.435 knots speed, with 101 pounds of steam in the boilers, 27.3 inches of vacuum, 108.8 revolutions, and a mean pressure in the cylinders of 57.94 pounds and 14.99 pounds.

COLOSSUS.

A three hours' full-power trial at sea of this battle ship was had May 28, 1886; ship at load draught of 24 feet 2 inches forward, 27 feet 3 inches aft; (normal draught being 25 feet 3 inches forward, 26 feet 3 inches aft). The mean results were: Pressure in boilers, 62.75; vacuum, 27; pressure in cylinders, starboard, 39.25 and 12.25; port, 39.03 and 12.33; revolutions, starboard, 85.3, port, 86.8; total, I. H. P., 7,069; speed, 15.448 knots. These results were exceeded at the six hours' trial in January, 1884, when the engines were in charge of the contractors, Messrs. Mandalay Sons & Co. The draught of the ship at that trial was 21 feet 3 inches forward, 24 feet 10 inches aft, and the mean results were: Pressure in boilers, 61.52; vacuum, 27.7; pressure in cylinders, starboard, 40.24 and 12.11; port, 40.92 and 11.97; revolutions, starboard, 90.02; port, 89.91; total, I. H. P., 7,488.23; speed, 16.53 knots. The I. H. P. required by the contract was 6,000.

The Colossus, a sister ship to the Edinburgh, was laid down at Portsmouth dockyard in June, 1879, launched in March, 1882, and finally completed for commission in 1886. They are both built of steel, carry compound armor, and are in design of the Inflexible type, with a central citadel 125 feet long, and two revolving turrets, *en echelon*. The principal dimensions are: Length, 325 feet; beam, 68 feet; mean draught, 25 feet 9 inches; displacement, 9,150 tons. The armor has a maximum thickness of 18 inches on the citadel and 16 inches on the turrets. Armament, four 12-inch 45-ton B. L.; five 6-inch 5-ton B. L.; four 6-pounder rapid fire; six Hotchkiss R. C.; four Nordenfelt 1-inch and four Gardner-45-inch. Twelve 14-inch Whitehead torpedoes, dischargeable through two above-water tubes, one each side of citadel, and one second-class torpedo boat are carried. The motive power consists of two sets of 3-cylinder vertical inverted compound engines driving 4-bladed twin screws, 10 boilers, with 28 furnaces, and a coal capacity of 970 tons. The authorized complement of officers and men is 396. Cost complete for sea, about $3,540,000 each.

HERO.

Described on pages 71 and 196 of "No. V." Had preliminary steam trials with natural draft, over the measured mile, August 17, 1886, with the following mean results: Pressure in boilers, 89; revolutions, 97.5; total I. H. P., 4,350; speed, 13.89 knots. The ship was drawing 19 feet 5 inches forward, 22 feet 6 inches aft, the normal draught being 22 feet forward, 24 aft. Some days later the forced-draft trial over the measured mile took place, the ship drawing 19 feet 8 inches forward, 22 feet 7 inches aft. The mean results were: Steam in boilers, 91.21; vacuum, 28.32; revolutions, 109.8; air pressure in fire room, equivalent to 1-inch water; total I. H. P., 6,159; speed, 15.5 knots; coal consumed per I. H. P., 2.58 pounds. The I. H. P. estimated to develop a speed of 15.5 knots with this ship at normal draught was 6,000.

ORLANDO.

On December 31, 1886, a preliminary run over the measured route between Cullercoats and Newbiggin, off Northumberland, was made with this vessel. A little over ¾ boiler-power was used, which developed, with natural draft, a mean speed of 17.11 knots. With forced draft a mean speed of 18.75 knots was realized over the course from Tynemouth to Newbiggin Church and return. On April 13, 1887, the ship being at her designed mean draught of 21 feet, the natural-draft trial took place outside of Plymouth, the mean of the four hours' trial being as follows: Steam in boilers, 127; in cylinders, 37.8, 20.3, 9.4, and 38, 20.7, 9.3; vacuum, 26.2; revolutions, 104.4 and 104.2; total I. H. P., 5,617; speed, 17.2 knots. The highest power obtained during the trial was 5,856, the contract calling for but 5,500 I. H. P.

A short run with forced draft was then made, developing 8,200 I. H. P., and a mean speed of 18.2 knots; but at one time during the run the speed reached 19.8 knots. The I. H. P. required under forced draft is 8,500.

On April 15, 1887, over the same course, the four hours' contractors' trial with forced draft took place, the ship drawing 19 feet 9 inches forward, 22 feet aft (normal 20 and 22 feet). The highest results obtained were: Steam in boilers, 130; in cylinders, starboard, 34.3, 31.8, 17.8, port, 36.5, 30, 16.3; revolutions, 119.3 and 119.6; vacuum, 26; total I. H. P., 9,018; speed of one run over the measured mile, 19.25 knots. The engines were stopped from full speed ahead in five seconds, from stop to full speed astern in four seconds, and from full speed astern to the same ahead in eight seconds.

On April 19, 1887, the final four hours' full-speed trials took place with equally satisfactory results, the ship being brought to her normal load draught by the placing of weights. The mean results of this trial were: Steam in boilers, 129; in cylinders, starboard, 34, 26.9, 16.5, port, 38.7, 26.4, 16.1; vacuum, 26.1 and 26.2; revolutions, 119.2 and 118.5; total I. H. P., 8,622; mean speed by patent log over the measured mile, 19 knots. The highest I. H. P. developed was 8,992, or 492 I. H. P. in excess of the contract.

The engines worked well throughout without hot bearings, and the boilers furnished a good supply of steam without priming. The steam steering gear was satisfactory, the helm being put over 70° in thirty seconds, and a complete circle of 1,440 feet diameter was made in three minutes.

SEVERN.

Described on page 196 of "No. V." The engine contractors' (Humphrys & Co.) full-speed trial with forced draft took place at the Nore, July 2, 1886. The draught of the ship was 15 feet 6 inches forward, 19 feet 9 inches aft, the normal draught being 16 feet forward, 20 feet aft. The mean results of the three hours' trial over the measured mile were: Pressure in boilers, 108.91; vacuum, 25.95; air pressure in fire-room equivalent to 1⅝ inches water; pressure in cylinders, high 53.59, low 21.84; revolutions, 122.73; total I. H. P., 6,158; speed, 18.176, which results considerably exceed the estimates. The maximum I. H. P. developed during the trial was 6,335, an excess of 335 I. H. P. over the maximum power estimated to be developed.

THAMES.

A sister ship to the Severn, except that the engines were designed to develop 5,700 I. H. P. On January 25, 1887, the ship was taken outside Plymouth Breakwater for the final contractors' (Penn & Co.) full-speed trials with forced draft. The ship was very light, drawing but 12 feet 3 inches forward, 17 feet 3 inches aft (normal draught, 16 feet forward, 20 feet aft). The mean results of the four hours' trial were: Pressure in boilers, 109.3; pressure in cylinders, starboard, 49.1 and 23.8, port 50.6 and 22.8; vacuum, starboard, 24.5, port 24.6; revolutions, starboard, 118.3, port 119; total I. H. P., 5,871; speed, 18.3 knots. The trial was considered very satisfactory.

ACORN.

One of the six composite gun vessels of the class of the Icarus, described on page 197 of "No. V," was laid down at Pembroke by the Milford Haven Company in 1883, launched during 1884, and completed for sea during the past year. A full-speed trial under forced draft, with all weights on board, took place June 4, 1886, the draught of the ship being 11 feet 6 inches forward, 14 feet 5 inches aft (normal draught 11 feet 6 inches forward, 14 feet aft). The mean results were: Pressure in boilers, 90.6; pressure in cylinders high 42.3, low 18.7; vacuum, 26.1; total I. H. P., 1,371; speed, 12.4 knots. The estimated power of the engines was 1,200 with forced draft.

On March 2, 1887, another forced-draft trial took place outside Plymouth Breakwater, the ship drawing 12 feet 7 inches forward and 15 feet aft, with the following mean results: Steam in boilers, 95 pounds; in cylinders, high 44.8 pounds, low 19.2 pounds; vacuum, 25.4 inches; revolutions, 99.5; total I. H. P., 1,445; speed, 12.23 knots.

FEARLESS.

Sister to the Scout, described on page 113 of "No. IV," launched March 20, 1886, at Barrow, had a four hours' steam trial under forced draft on December 17, 1886. The ship was drawing 11 feet 6 inches forward, 13 feet 6 inches aft (normal draught, 12 feet 6 inches and 14 feet 6 inches). The mean speed realized was 17 knots. Owing to the lack of accommodations for a large crew, the number of torpedo discharging tubes has been reduced from eleven to seven. The cost of each of these vessels, complete for sea, is about $495,000.

CURLEW—LANDRAIL.

Described on page 197, of "No. V." Owing to faulty design these vessels draw, with all their proposed weights on board, 2 feet 4 inches more water than was intended. The Curlew had her final steam trials over the measured mile outside of Plymouth, July 21, 1886. With but 90 tons of coal on board her draught was 10 feet 8 inches forward; 11 feet 8 inches aft. The proposed coal supply is 250 tons, and the normal draught is 10 feet forward, 11 feet aft. The mean results of the trial were: Pressure in boilers, 110; vacuum, 24; revolutions, 197; total I. H. P., 1,452; speed, 15.081 knots. The forced-draft arrangements are bad, and the fire room is said to be unbearable when it is used.

The Landrail had her preliminary contractor's trial June 21, 1886, for four hours, with natural draft. The mean results were: Pressure in boilers, 95.9; pressure in cylinders, starboard, 50.8 and 9.9; port 47.3 and 10.6; vacuum, starboard, 25.3, port, 23.9; I. H. P., 828; speed, 12.65 knots. On June 23, 1886, the four hours' forced-draft trial took place, when a mean speed of 14 knots was developed. At both trials the ship was light, drawing 9 feet 11 inches forward, 10 feet 6 inches aft (normal draught 10 feet 11 inches), and at the last trial the weather was unfavorable, there being a heavy beam sea and stiff breeze.

ARCHER—BRISK—COSSACK—MOHAWK—PORPOISE—TARTAR.

Described on pages 85, 86, 139, and 196 of "No. V." The Archer was taken outside the Plymouth Breakwater, December 29, 1886, for the contractor's full-speed trial with natural draft, with the following mean results: Pressure in boilers, 100 pounds; pressure in cylinders, starboard, 44.8 and 14.5, port, 45.4 and 12.7; vacuum, starboard, 24, port, 22.5; revolutions, starboard, 136.3, port, 138.5; total I. H. P., 2,404; speed, 15 knots. The engines worked well and the trial was considered satisfactory. On January 7, 1887, an attempt was made to have the forced-draft trial, but after a short run the trial was stopped, owing to the heavy head sea and strong wind. When steaming at full speed a great deal of water was taken aboard, but she proved a fairly good sea boat. On this short trial 4,256 I. H. P. was developed, and a speed of 18.2 knots. At both of these trials the ship was at her normal load draught, 12 feet 6 inches forward, 14 feet 7 inches aft. On February 10, 1887, she had a successful four hours' trial with forced draft, the ship being at her normal load draught, with mean results as follows: Pressure in boilers, 127.2; pressure in cylinders, high, 61.4 and 64.1, low, 20.9 and 20.2; vacuum, 24.4 and 24.1; revolutions, 156.7; total I. H. P., 3,982; speed, 17.2 knots. The maximum results obtained were 4,122 I. H. P. and 17.8 knots speed. The coal consumption is said to have been at the rate of 1.5 pounds per I. H. P. per hour.

The Brisk, at the same draught, was tried on January 3, 1887, outside Plymouth Breakwater. The mean results of the contractor's four hours' trial, with natural draft, were: Pressure in boilers, 116; pressure in cylinders, starboard, 45.1 and 16, port, 45.2 and 15.8; vacuum, starboard, 24, port, 24.3; revolutions, starboard, 137.8, port, 137.2; total I. H. P., 2,617; speed, 15.75 knots. The engines were reversed from full speed ahead to full speed astern in 6 seconds; from full speed ahead to stop in 4 seconds, and from full speed astern to the same ahead in 4 seconds. Though there was a heavy sea running and a strong wind, the ship and engines behaved well throughout. On January 22, 1887, an attempt was made to have the forced-draft trial, the ship being at normal load draught, but before the end of the second hour the boiler tubes became leaky and the trial had to be discontinued. The results of one run were 3,954 I. H. P., and 18 knots speed.

The Cossack, at normal load draught, was tried at the same place December 30, 1886; the mean of the four hours', contractor's, natural-draft trial giving the following results: Pressure in boilers, 108; pressure in cylinders, starboard, 42.7 and 15.2, port, 39.4 and 14.2; vacuum, 24.6; revolutions, starboard, 134.7, port, 134; total I. H. P., 2,342; speed, 15.75 knots. The highest power developed was 2,557, and a speed of 16.25 knots.

The forced-draft trial was attempted on January 1, 1887, but, as in the case of the Brisk, the trial had to be stopped at the end of the second hour owing to leaky tubes. The mean results for two hours were: Pressure in boilers, 118; pressure in cylinders, starboard, 60.5 and 20.6, port, 61 and 21.8; vacuum, starboard, 24, port, 26; revolutions, 158.5; total I. H. P., 3,991 speed; 17.8 knots.

On February 5, 1887, a complete trial of four hours was made with forced draft, the ship being at her normal load draught. The mean results of the trial were: Pressure in boilers, 124.3; pressure in cylinders, starboard, 57.5 and 20.5; port, 27.7 and 21.4; vacuum, 24.9 and 23.7; revolutions, 156.1; total I. H. P., 3,851; speed, 17.6 knots. The maximum I. H. P. developed was 4,003; speed, 18 knots.

The Mohawk, at normal load draught, had her contractor's trials with natural draft on June 22, 1886. The results were: Pressure in boilers, 100; vacuum, 24.5; revolutions, 142; total I. H., P. 2,914; speed, 15.56.

The Porpoise was taken outside of Portsmouth on March 8, 1887, for her steam trials, and, unlike the other vessels of her class, had a very successful series, without any accident. With natural draft the results were 2,477.5 I. H. P., and a speed of 16 knots. With forced draft the mean results of three runs over the measured mile were 3,943 I. H. P., and 17.5 knots speed, theengines making 158 revolutions. At both trials the coal consumption was 2.01 pounds per I. H. P. per hour. The draught of the ship was 12 feet 6 inches forward, 14 feet 6 inches aft, her normal load draught.

The Tartar was tried outside of Sheerness, March 30, 1887, with satisfactory results. The ship was at normal load draught, and realized under forced draft 17.28 knots. The I. H. P. developed was 3,824; revolutions, 157; the steam in the boilers was 120 pounds, and the vacuum in condensers 25.5 inches.

All of these trials were satisfactory as far as the power developed by the engines was concerned, they being designed to develop 2,400 I. H. P. with natural draft, and 3500 I. H. P.. with forced draft.

The cost of each of these ships, complete for sea, is about $545,000.

RATTLER—WASP—BRAMBLE—LIZARD.

The first of these was taken outside of Sheerness January 31, 1887, for the four hours' steam trial with natural draft. The mean results were: Pressure in boilers, 125; vacuum, 25; revolutions, 153.2; I. H. P. 653.

On February 2, 1887, the forced-draft trials took place with results as follows: Pressure in boilers, 125; vacuum, 25.5; revolutions, 202.6; total I. H. P., 1,291; speed, 14.2 knots; coal consumption, 23 cwt. per hour. The draught of the ship at this trial was 9 feet 6 inches forward, 11 feet 6 inches aft (mean normal draught, 11 feet 2 inches). The engines worked smoothly throughout, and the boilers furnished an ample supply of steam without priming.

On January 28, 1887, the Wasp had the contractor's four hours' trial with natural draft, off Sheerness, her draught of water being 9 feet 8 inches forward, 11 feet 8 inches aft. The mean results of the trial were: Pressure in boilers, 113; vacuum, 26.2; revolutions, 162.7; I. H. P., 693.7; speed, 11.81 knots.

The forced-draft trials took place January 29, 1887, the ship being at the same draught of water. Mean results: Pressure in boilers, 140 pounds; vacuum, 27; revolutions, 193; I. H. P., 1,197; speed, 14.2 knots. The engines worked smoothly throughout and the boilers were satisfactory in every respect.

The Bramble was taken outside of Devonport on April 5, 1887, for the first of her natural draft steam trials, drawing 9 feet 7 inches forward, and 11 feet 10 inches aft. The trial was considered very satisfactory, as there was a total absence of priming or hot bearings.

The results were: Pressure in boilers, 120.9; pressure in cylinders, 43.1, 14.9, 9.4; vacuum, 25.3; revolutions, 145; I. H. P., 620; mean speed by patent log, 11.7 knots.

On April 7, 1887, the forced-draft trials took place with the following mean results: steam in boilers, 140, in cylinders, 47.3, 27.7, 12.8; vacuum, 26.4; revolutions, 183.1; I. H. P., 1,079; speed, 13.4 knots.

The Lizard had her first trials outside the same port on April 4, 1887, with similarly satisfactory results. She was loaded down to a draught of 9 feet 7 inches forward, and 11 feet 10 inches aft, as the other vessels of her class had been.

The trial was with natural draft, and gave the following mean results for four hours: Pressure in boilers, 124.5, in cylinders, 45.9, 16.7, 10.7; vacuum, 26.5; revolutions, 150.9; I. H. P., 685; speed, 12.2 knots; coal consumption per I. H. P., 1.89 pounds per hour.

The engines were stopped from full speed in 5 seconds; from stop to full speed astern, 8 seconds; from full speed astern to full speed ahead, 7 seconds.

On April 6, being at the same draught, a forced-draft trial took place, with the following satisfactory results: steam in boilers, 120 pounds; in cylinders, 49.6, 22.6, 12.4; vacuum, 26.75; revolutions, 182.9; I. H. P., 1025; speed (pat. log), 13.5 knots; coal per I. H. P., 2.12 pounds.

In all these vessels the anticipated results were exceeded, the engines having been designed to develop 1000 I. H. P. and a speed of 13.75 knots. Those of the Rattler were built by Hawthorne, and the Wasp's by the Northeastern Engineering Company. The builders of the Lizard and Bramble, Harland & Wolff, of Belfast, also built their engines. They are all of the horizontal triple-expansion type, with cylinders 18½ inches, 29 inches, and 43 inches diameter; stroke 24 inches, driving single two-bladed screws.

The boilers are two in number, cylindrical, with two furnaces in each. The cost of these vessels complete for sea is about $196,000 each.

RATTLESNAKE

Off Portsmouth, the contractors' three hours' forced-draft trial took place February 3, 1887, the vessel being brought down to a draught of 6 feet 9 inches forward, 9 feet 11 inches aft, by iron ballast. The mean results were: Pressure in boilers, 136; vacuum, 25; revolutions, starboard, 311; port, 308; pressure in cylinders, starboard, 59, 28, and 13; port, 58, 28, and 11; I. H. P , 2,718.27; speed, 18.779, the mean of six runs over the measured mile. The engines, which were built by Laird, are of the vertical triple-expansion type, with cylinders 18½, 27, and 42 inches diameter; stroke, 18 inches, and were designed to develop 2,700 I. H. P., with forced draft and a speed of 19 knots on a mean draught of 8 feet of water; this draught is slightly exceeded. Boilers of the locomotive type, four in number. Twin, three-bladed screws of manganese bronze, 6 feet 6 inches diameter, 7 feet 6 inches pitch.

The coal supply of 100 tons is sufficient for 16.7 days' steaming at 10 knots, or 4,000 knots.

On February 11, 1887, a second trial under forced draft was made under more favorable circumstances of wind and weather, when the first results were considerably exceeded.

The maximum I. H. P. developed was 3,100, and the mean I. H. P. for the trial was 2,860, or 160 in excess of the contract; 19.5 knots was the mean speed of several runs over the measured mile, with a mean number of revolutions of 322.

On February 7, 1887, a six hours' trial, at 11 knots speed, took place, when it was ascertained that 373 I. H. P. and 160 revolutions must be developed to maintain that speed.

The coal consumption at this trial was two pounds per I. H. P. per hour, at which rate her coal supply would enable her to steam 2,800 miles, or slightly over the distance between Liverpool and New York.

The mean draught of this vessel, with normal weights on board, is found to be 9 feet, or 1 foot greater than as originally designed.

ALACRITY.

Described on page 200 of "No. V." On May 18, 1886, and August 10, 1886, unsuccessful attempts were made to have full steam trials with forced draft, but in each case the boilers primed so badly and the tubes so leaked that the trials had to be abandoned. On the first trial it is claimed that one run was made over the measured mile at 18.7 knots, the engines making 130 revolutions. On the second trial a speed of 18.5 knots is claimed for a short time. On August 24, 1886, a satisfactory trial was had with weights on board, when the engines worked up to 3,100 I. H. P. and developed a speed of 16.99 knots. Shortly after this trial she sailed for China, to which station she is assigned as a regular cruiser.

The battery placed on board is four 5-inch 40 cwt. B. L. on sponsons, two forward, two aft; four 6-pounder rapid-fire guns on hurricane deck in waist; two 5-barreled Nordenfelts. A similar armament is kept in store at Malta for the Surprise, a sister vessel, she being at present assigned to the Mediterranean station as a tender and yacht for the commander-in-chief.

FRANCE.

VESSELS LAID DOWN.

JEAN BART—DUPUY DE LÔME.

In October, 1886, the French Government ordered these steel, twin-screw, vessels to be laid down, the former at the Rochefort dockyard, and the latter at the dockyard at Brest. They are the latest development of the "cruiser" class of war vessels, and are designed for a speed of 19 knots with forced draft. The principal dimensions are: Length on W. L., 352 feet; beam, 43 feet 6 inches; depth, 30 feet; mean draught, 18 feet 10 inches; and displacement, 4,162 tons. The armaments will consist of four 6.3-inch (16-centimetre) B. L. on sponsons, six 5.5-inch (14-centimetre) in broadside, four 3-pounder rapid fire, six 37-millimetre Hotchkiss R. C., and a supply of Whitehead torpedoes dischargeable through four tubes. They are double-decked, and have a complete steel protective deck. It is intended to complete them for sea in 1890.

ALGER—ISLY.

The first was ordered to be laid down at the Cherbourg dockyard about the same time as the Jean Bart and Dupuy de Lôme, and the second was ordered to be laid down in March, 1887, at Brest. They are similar in construction to the Amiral Cécille, described on pages 80 and 202 of "No. V," but smaller, being of nearly the same dimensions as the Jean Bart, and carrying a similar armament. The length is 346 feet; beam, 45 feet 3 inches; depth, 29 feet 4 inches; mean draught, 18 feet; displacement, 4,123 tons. A speed of 19 knots is expected, and a coal supply sufficient to steam 3,600 miles at 13 knots will be carried. The cost of hull and machinery for each, without equipment of any kind, is estimated to be $900,000.

MOGADOR.

M. Lagane, the constructing engineer of the Société des Forges et Chantiers de la Méditerranée, at the desire of the French Government, has designed a rapid, protected, steel cruiser of the following dimensions: Length, 351 feet; beam, 45 feet; depth, 30 feet 6 inches; draught aft, 20 feet; and displacement, 4,325 tons. The armament to be four 6.3-inch (16-centimetre) B. L. on sponsons, six 5.5-inch (14-centimetre) B. L. in broadside, four 3-pounder rapid-fire guns, six 37-millimetre H. R. C., and a supply of Whitehead torpedoes. The engines to be of the triple-expansion type and to develop 8,200 I. H. P. and a speed of 19 knots. The Government ordered the above-named company to begin the building of the vessel in March, 1887.

TROUDE—LALANDE.

Two rapid, protected, steel cruisers of smaller size than the Alger, similar in construction to the Forbin and Surcouf, described on page 302 of "No. V," but on slightly different lines.

The French Government, desirous of obtaining the greatest possible speed on the least displacement, sent proposals to the large ship-building companies of the country, and of these five took part in the competition for building this type of cruisers. The Government did not limit the designers to length, beam, or displacement, and placed a limit only on the maximum draught of water aft. They required the vessel, though, to fill the following conditions on the least displacement possible: To realize a speed of 18 knots for twelve hours with natural draft; 19.5 knots for two hours with forced draft; to have a coal supply sufficient to steam 2,400 miles at 10 knots; to carry a main battery of two 5.5-inch (14-centimetre) B. L.; and to have a protective deck of 1.6 inches (40-millimetres) thickness. The design submitted by the "Société de la

Gironde," of Bordeaux, was accepted for two vessels to be named the Troude and Lalande, and this company has undertaken to build the vessels for the price offered, $550,000 each. The principal dimensions are: Length, 311 feet 7 inches; beam, 31 feet 2 inches; mean draught, 14 feet; displacement, 1,877 tons. Armament: Two 5.5-inch (14-centimetre) B. L. on side sponsons; three 3-pounder rapid-fire; four 37-millimetre H. R. C., and a supply of Whitehead torpedoes dischargeable through five tubes. A light fore-and-aft rig will be fitted. The complement will be 160 officers and men. The protection will be similar to that before described for the Forbin. The estimated power of the engines is 6,000 I. H. P. The similarity to the Forbin and Surcouf, designed by the inspector-general, M. de Bussy, to fulfill the same requirements is very noticeable. They were laid down in March, 1887, and it is intended to complete them for sea in 1888, twenty-two months from the signing of the contract.

COETLOGON—COSMAO.

Sister vessels in all respects to the Forbin and Surcouf, described on page 202 of "No. V," were ordered in March, 1887, to be laid down at Havre by the firm of M. Normand et Cie.

Unable, owing to the size of their ship-yard, to construct vessels of such length, this firm was compelled, much to the regret of the Government, to decline the contract in April, 1887; accordingly, the first was given to the Société de la Gironde, and the other to the Compagnie Transatlantique.

CHANZY—DAVOUST—SUCHET.

Rapid protected cruisers of 3,027 tons displacement, laid down in March, 1887, the first at St. Nazaire by the Société des Chantiers de la Loire, and the last two at Toulon.

Their principal dimensions are: Length, 297 feet 6 inches; beam, 40 feet; depth, 27 feet 3 inches; draught, forward, 14 feet 10 inches; aft, 20 feet 2 inches; mean, 17 feet 6 inches. They will carry batteries of four 6.3-inch (16-centimetre) B. L., four 3-pounder R. F. G., six 37-millimetre H. R. C., and four torpedo-launching tubes. The motive power consists of two sets of independent compound engines driving twin screws, and estimated to develop 9,000 I. H. P. with forced draft. The speed expected with this power is 20 knots; 480 tons of coal will be carried, which is sufficient to enable the vessels to cover 4,000 knots, at 12.5 knots per hour. They will be fitted with 4-masted fore-and-aft rigs.

BENGALI.

A paddle-wheel, armed dispatch vessel, ordered July, 1886, to be built by Normand & Cie. Principal dimensions are: Length, 178 feet 10 inches; beam, 24 feet 6 inches; depth, 12 feet; mean draught, 7 feet; displacement, 547 tons. The hull to be built of steel and divided into four water-tight compartments. The contract price for hull and machinery is $135,100.

The French naval department proposes to build a class of vessels locally known as "les mères Gigognes," which are intended for service as torpedo-depot vessels. They are intended to be an improvement on that class of vessels as they exist in foreign services; as they are to be armored and are to carry heavy armaments both for their own protection and that of their torpedo flotilla, of six boats, which it is proposed to attach to each of them.

Plans for the construction of the first of these vessels were invited from French designers in April, 1887. The following conditions only were required to be filled. To carry a water-line belt of 13.8-inch steel, and two barbette towers clad with 11.8-inch steel. An armament of two 13.4-inch (34-centimetre) B. L., to be mounted in the barbettes, and a secondary battery of four 3-pounder R. F. G., and six 37-millimetre H. R. C., to be suitably placed. Arrangements for discharging torpedoes are also to be fitted. The trial speed to be at least 16 knots. A coal supply sufficient to enable the ship to cover 2,000 knots at the rate of 12 knots per hour to be carried; also, 160 tons additional for the supply of the six torpedo-boats.

VESSELS LAUNCHED.

HOCHE.

A battle ship similar in general dimensions to the Marceau, described on page 44 of "No. V," was launched at L'Orient, September 29, 1886. The Hoche was laid down in 1880, and it is expected that she will be 70 per cent. completed by the end of 1887. It is intended to complete her for sea in 1890. She resembles in general the French type of armor clads; having a great tumble home to her sides, a long ram bow, and a receding stern. She has a complete water-line belt, an unarmored battery for the lighter guns of the armament, and armored positions for the heavy guns. The belt is compound 17.7 inches to 13.8 inches thick; the protective deck extends over the top of the belt, and is steel 3.15 to 3.54 inches thick; and the heavy gun positions, situated one forward and one aft on the midship line, and one each side in the waist, are protected by 15.75-inch compound armor. These latter positions are of peculiar construction, consisting of a fixed armored tower extending from the protective deck to the platform on which the gun-carriage rests, raised slightly above the level of the battery deck. From that point to above the level of the gun it is a turret revolving with the gun, and over the whole is a steel shield in shape the frustum of a cone, supported from the hurricane or superstructure deck.

The armament consists of two 13.4-inch (34-centimetre) B. L., one in each of the midship turrets; two 10.6-inch (27-centimetre) B. L., one in each of the waist turrets, which are sponsoned out well clear of the upper works; eighteen 5.5-inch (14-centimetre) B. L., in broadside in the unarmored central superstructure which occupies the upper deck between the turrets—the forward and after pairs having bow and stern fire—and twenty R. F. G. and H. R. C. A supply of Whitehead torpedoes, dischargeable through four tubes, and two above-water carriages in the stern, will be carried.

There will be two masts, each fitted with two armored tops. The motive power consists of two sets of 3-cylinder compound vertical engines driving twin screws, the steam being supplied by twelve cylindrical 3-furnace boilers. As originally designed a speed of 16 knots was expected with natural draft only, and a developed power of about 7,000 I.H. P. The application of forced draft has raised the expected I. H. P. to 12,000, and the estimated speed to 17½ knots. The coal capacity is 600 tons, sufficient for 4.2 days steaming at full speed.

The cost complete will be about $3,100,000.

NEPTUNE.

An armored barbette battle ship, a sister to the Marceau, described on page 44 of "No. V," and carrying a similar armament, was launched May 7, 1887, from the Government dockyard at Brest, where she was laid down in 1880. It is intended to complete her in 1889.

MARCEAU.

Described on page 44 of "No. V," was launched May 24, 1887, at La Seyne, from the yard of Les Forges et Chantiers de la Méditerranée, where she was laid down in 1880.

COCYTE.

An armored coast-defense gun vessel laid down in 1882, and launched from the Cherbourg dockyard January 13, 1887. She is a sister to the Achéron, laid down at the same time and place, launched May, 1885, and described on page 116 of "No. IV." The motive power consists of two sets of horizontal compound direct-acting engines of 1,700 I. H. P., driving twin screws 9 feet 3 inches diameter. The complement will be seventy officers and men. Cost, complete, about $500,000. It is intended to have all of the class completed for sea in 1888.

MITRAILLE.

A smaller type of armored gun vessel, sister to the Fusée, described on pages 89 and 202 of "No V." Launched from Rochefort dockyard July 3, 1886, and will be completed during 1887, at a cost of about $450,000. This class have their bottoms wood-sheathed and coppered.

TAGE.

This large protected steel cruiser, described on page 201 of "No. V," was launched October 28, 1886, and is expected to be completed for sea in 1888. She was commenced in November, 1885.

INCONSTANT—PAPIN—FULTON.

Small composite, single screw, bark-rigged cruisers laid down in 1882; the first two at Toulon dockyard, and the last at L' Orient. They were launched July 14, 1886, November 10, 1886, and January, 1887, respectively, and are similar in all respects. The principal dimensions are: Length, 199 feet 6 inches; beam, 28 feet 5 inches; depth, 15 feet 5 inches; draught, forward, 9 feet 6 inches; aft, 12 feet 9 inches; displacement 811 tons; armament, three 5.5-inch (14-centimetre) B. L., pivots, one being on the short top-gallant forecastle, one 4-inch (10-centimetre) B. L., pivot on the poop; five Hotchkiss revolving cannon. The engines are of the horizontal, compound, back-acting, three-cylinder type, and drive one four-bladed screw. The estimated speed of the first two is 12 knots, and of the last 15 knots. The sail area is 8,850 square feet, ample for efficient working under sail. Coal capacity 145 tons; complement, 116 officers and men. Cost, complete, about $200,000 each. It is intended to complete them for sea in 1887.

GABRIEL CHARMES.

A new type of small gunboat of great speed, designed by Admiral Aube, constructed during the past year by Les Forges et Chantiers, at La Seyne; and launched in November, 1886. She has already had a number of trials of her armament and engines. In form and mode of construction this vessel has great similarity to a torpedo-boat, and is, in fact, but a first-class torpedo-boat, with a 5.5-inch (14-centimetre) B. L. R., mounted forward in place of an armament of Whitehead torpedoes. She is, of course, strengthened and more heavily built to withstand the shock of discharge of so large a piece of ordnance. The gun is mounted 26 feet from the bow; has a train of 10° on either side of the keel, and is protected by a steel shield. Immediately abaft the breech of the gun is an armored conning tower, within which an ingenious mechanism enables the commanding officer to himself direct all the operations of his vessel.

The principal dimensions are: Length, 132 feet 6 inches; beam, 12 feet 6 inches; draught, aft, 6 feet 7 inches; displacement, 74 tons. The motive power consists of compound two-cylinder engines, estimated to develop 560 I. H. P., which, it was expected, would develop a speed of 19 knots. The weight of the machinery, boilers, &c., is but 22 tons, of the hull 26 tons 8 cwt., and of the gun and carriage 11 tons 5 cwt. The cost is about $55,000.

It is said to have been demonstrated, on trial, that a roll of 45° would capsize the boat, and that it would be dangerous to send her to sea in even a moderate sea. It is also said to be impossible to fire her gun except in smooth waters. In December, 1886, some preliminary firing and steam trials took place. At the former, after twelve shots with service charges, it was found that a number of rivet heads had been sheared off in the plating of the forward part of the deck by the concussion. No authentic data have been obtained of the steam trials, but it is claimed that she developed a speed of a little more than 20 knots, in December, in a run near Hyères, without forced draft, the weather being calm and the sea smooth. Another account gives the speed at 19.06 knots, and in January, 1887, she is said to have realized a speed of 19.85 knots, without forced draft, weather and sea being calm. In April, 1887, after a series of trials, her maximum speed was stated to be 18.8 knots. As a gun platform the vessel is a decided failure, a very slight sea causing such a lively motion as to make anything like accurate target practice an impossibility. This has been demonstrated by several unsuccessful attempts to use her gun in a seaway. The type does not appear to be favored by French officers generally.

CONDOR—EPERVIER—FAUCON—VAUTOUR.

Small cruisers of high speed, known officially as "croiseurs-torpilleurs," laid down the latter part of 1882, and described on page 117 of "No. IV." They were launched, the first on May 17, 1885, and the last three during 1886. In addition to the main battery of five 3.94-inch B. L., six 37-millimetre H. R. C. will be mounted, and a supply of twelve to sixteen Whitehead torpedoes will be carried. The engines are of the 3-cylinder horizontal compound type and are expected to develop 3,200 I. H. P. with forced draft and a speed of 18 knots. Four locomotive-type boilers furnish the steam. The complements of officers and men are 125. Cost, complete, about $580,000. Intended to be completed for service during 1887.

LANCE—SALVE.

The last of the eight "avisos-torpilleurs" of the Bombe class, described on page 117 of "No. IV." Launched April 20, 1886, and February 6, 1886, respectively.

SCORFF—MEURTHE—RANCE—DURANCE—DRÔME.

Composite-built armed transports, built at Government dockyards. The last two were launched January 10, and March 11, 1887, and will be completed during the year. They are single screw, bark-rigged, spread 13,000 square feet of canvas, and carry crews of 105 officers and men. Their principal dimensions are: Length, 209 feet 10 inches; beam, 34 feet 6 inches; depth, 13 feet 6 inches; mean draught, 14 feet 9 inches; displacement, 1,597 tons. They are armed with four 5.5-inch B. L., two 3.54-inch B. L., and four 37-millimetre H. R. C.; have a speed of 12 to 14 knots, and cost complete (average) about $400,000 each.

AUBE—EURE—MANCHE.

Similar vessels, with somewhat different dimensions, built by contract, the first two launched November 10, 1885, April 5, 1886, and the last not yet launched. Dimensions: Length, 208 feet 9 inches; beam, 34 feet 4 inches; depth, 21 feet 6 inches; mean draught, 15 feet 1 inch; displacement, 1,580 tons. Complement and armament the same as the Durance. The first two are complete, and the last will be completed in 1889.

JOUFFROY.

A small wooden, paddle, gun and dispatch vessel, destined for service on the rivers of Senegal, was launched April 21, 1887, from the yard of Caudan at L'Orient. She has a displacement of 310 tons, a length of 115 feet, beam 18 feet, and draws 5 feet 6 inches of water. An armament of two 3.54-inch (9-centimetre) B. L. and four H. R. C. will be carried. The expected speed is 8 knots. The complement will be 37 officers and men.

STEAM TRIALS.

In France these trials consist of four series:

(1) Speed trial of six hours' duration over a measured base, the ship being brought to her load draught, engines working at maximum power, all fires lighted, and the draft forced. The pressure in boilers to be equal to and limited by the load on the safety valve.

(2) Speed trial of two hours' duration to show the utmost capacity of the machinery, the draft being forced and the boilers managed so as to produce their maximum amount of steam so long as they continue to show good behavior.

(3) Trial for good performance, of twenty-four hours' duration, and to ascertain the coal consumption per hour per I. H. P. developed; the engines to be worked at full power, all fires lighted, the pressure in the boilers to be equal to and limited by the load on the safety-valve; natural draft only to be used, assisted, if necessary, by blowers, but without closing the fire-rooms.

(4) Progressive speed trials with natural draft, the duration at each speed being four hours, to ascertain the results of different conditions of working the engines.

Throughout these trials indicator cards are taken at intervals of twenty minutes.

On the full-power trials the throttle-valves are kept wide open and the cut-offs are not touched during the run.

VESSELS COMPLETED FOR SEA AND TRIED.

AMIRAL COURBET.

A casemate battle-ship with unarmored barbettes, one each side on upper deck, formerly named the Foudroyant, was laid down at the Toulon dockyard in 1876, launched the latter part of 1882, and finally completed for sea during 1886. She is built of iron and steel, has a long ram bow, and was originally intended to be ship-rigged, spreading 24,000 square feet of canvas, but this has been changed to a 3-masted fore-and-aft rig, with two military tops on each mast. Principal dimensions: Length, 311 feet 7 inches; beam, 69 feet 8 inches; mean draught, 24 feet 1 inch; displacement, 9,652 tons; armament, four 13.4-inch B. L. in main-deck casemate; four 10.6-inch B. L., one in bow, one in stern, one each side on upper deck in barbettes; six 5.5-inch B. L. in broadside upper deck; twelve 37-millimetre H. R. C., and a supply of Whitehead torpedoes dischargeable through four above-water tubes, one on each bow and quarter. The armor is iron and consists of a belt 15 to 8.7 inches thick from 5½ feet below the water-line to 4 feet above, and complete to near the stern, a central casemate, a conning tower, and a complete protective deck, over top of belt, formed of 1.2 inch steel on 2-inch iron plates. The motive power consists of two sets of Woolf compound vertical 3-cylinder engines, driving twin 4-bladed screws. Twelve 3-furnace elliptical boilers supply the steam. A coal supply of 560 tons is carried, and a complement of 680 officers and men. Cost complete, about $2,500,000.

The steam trials took place in 1886, and developed 6,016 I. H. P., with natural draft, 8,088 I. H. P. with forced draft, and a mean speed of 14.2 knots on a consumption of 2.2 pounds of coal per hour per I. H. P. with natural draft, and 2.5 pounds with forced draft.

INDOMPTABLE—TERRIBLE.

Two of four powerful battle-ships, of which the others are the Requin and Caïman, laid down in 1877, the first three at Government dockyards, and the last at Bordeaux, by the Société Anonyme des Chantiers, &c. The Terrible was completed for service during the spring of 1887. They, like their sister vessels, are built of iron and steel, the outer skin of the under-water body being of iron; have powerful ram bows; are fitted with two masts with military tops, are divided into numerous water-tight compartments, and have high freeboards, carrying the axes of their barbette guns 21 feet above the water. The armor protection consists of a complete belt, 19⅝ to 13 inches thick, compound, 7 feet 6 inches wide, of which 5 feet is below the water-line; two pear-shaped barbette towers on the midship fore-and-aft line 17¾ inches thick, ammunition tubes 7.8 inches thick, and a conning tower forward of the four smoke-pipes 11.9 inches thick; also a complete steel-protective deck over top of belt 3.15 inches thick, increased to 3.94 inches over engines, &c. Principal dimensions of the ships: Length, 278 feet 2 inches; beam, 59 feet; mean draught, 23 feet 7 inches; displacement, 7,168 tons; armament, two 16.5-inch B. L., one in each barbette; four 4-inch B. L. on upper deck; as many H. R. C. as can be conveniently mounted, and a supply of Whitehead torpedoes dischargeable through above-water tubes. The motive power consists of two sets of compound vertical 3-cylinder engines, driving twin 4-bladed screws, and supplied with steam by twelve cylindrical 2-furnace boilers. The I. H. P. expected was 6,000, which was estimated to drive the ship 14.5 knots. The amount of coal carried is 800 tons, and the complement of officers and men 300.

The Indomptable was launched at L'Orient on September 18, 1883, and was completed during 1886. Her final steam trials took place at Brest in August, 1886, when a speed of 15 knots was realized, and 13.5 knots was established as the maximum cruising speed. The bow-wave formed at maximum speed was very great.

The trials of the Terrible were equally satisfactory.

DUGUESCLIN.

Armored cruiser, laid down at Rochefort dockyard 1876, launched April 7, 1883, completed and had final steam trials August, 1886. She is built of iron and steel, is sheathed with wood and copper, has a ram bow, is brig-rigged, spreading 24,000 square feet of canvas, carries a crew of 450 officers and men, and a coal supply of 450 tons. The principal dimensions are: Length, 265 feet 8 inches; beam, 57 feet 2 inches: mean draught, 23 feet 3 inches; displacement, 5,869 tons. Armament four 9.45-inch B. L. in barbette towers, one 7.5-inch B. L. in bow, six 5.5-inch B. L. in broadside, two 6-pdr. R. F., twelve H. R. C., and a supply of Whitehead torpedoes dischargeable through two above-water tubes, abreast the foremast. The armor portection consists of a complete iron belt 9⅕ to 6½ inches thick; four barbetts, one each side forward, two on midship fore-and-aft line, aft, with 8-inch compound armor, a 2-inch conning tower on forward bridge, and a complete iron protective deck 2 inches thick over top of belt.

The motive power consists of two sets of compound vertical 3-cylinder engines driving twin four-bladed screws, and supplied with steam by eight cylindrical 2-furnace boilers. The estimated I. H. P. is 4,100 and speed 14 knots. These results were reached at the trials in August last, but the ship is down by the head slightly. Cost, complete, about $1,500,000.

SFAX.

A powerful protected steel cruiser, built at the Government dockyard at Brest, where she was laid down in 1883 and launched May 29, 1884, had her first steam trials off Brest during the first week of May, 1887. With natural draft, the mean I. H. P. developed for four hours was 4,333, and the speed 15.9 knots. With forced draft, the mean results of a six hours' trial were: I. H. P., 6,034; revolutions, 78; mean speed, 16.84 knots. The trials for coal endurance showed that with full natural draft speed the consumption was 1.96 pounds per hour per I. H. P. developed, and with forced draft it was 2.10 pounds. During these trials the draught of water was 19 feet 4 inches forward, 25 feet 1 inch aft, which was in excess of the normal designed draughts of 19 feet 8 inches and 24 feet 8 inches. Notwithstanding this fact, and the fact of the I. H. P. falling much below the estimated power of the engines (5,000 I. H. P. natural, and 7,500 I. H. P. forced draft), the speed realized exceeded the maximum estimated forced draft speed of 16. 5 knots. It is proposed to alter the screws, and with the new ones of improved design it is expected to obtain 90 revolutions of the engines, and develop 7,000 I. H. P.

This vessel is built of steel throughout, and is sheathed with wood and coppered, has a ram bow, is full ship-rigged, spreading 21,420 square feet of canvas, is double decked, and has an under-water, curved steel protective deck 1.5 inches thick. The under-water body is divided by one longitudinal and sixteen transverse water-tight bulkheads. The space between the protective deck and the deck above is also minutely subdivided, the spaces being used for store-rooms and coal-bunkers. Additional protection to the stability is given by a water-line belt of cellulose. The ammunition tubes, or hoists, are armored, and all the guns are protected by steel shields. The principal dimensions are: Length on water line, 288 feet 8 inches; beam, 49 feet 2 inches; mean draught, 22 feet 4 inches; displacement, 4,488 tons. Two sets of independent 2-cylinder horizontal, compound direct-acting engines drive twin screws of 17 feet 6 inches diameter. Steam is supplied by twelve cylindrical 2-furnace boilers in two separate compartments.

The armament consists of six 6.3-inch (16-centimetre) B. L., four mounted on sponsons, with bow and stern fire, and two in recessed ports forward, with bow and beam fire; ten 5.5-inch (14-centimetre) B. L., in broadside on the gun-deck, and eight H. R. C.

The first cost of hull and machinery, without equipment of any kind or armament, was estimated at $965,000. The full coal supply of 800 tons is estimated to give an endurance of 25.8 days at 10 knots per hour.

CONDOR.

This vessel, before described, had her steam trials off Rochefort, during December, 1886, and realized a speed of 17.7 knots without forced draft over the measured basis.

BOMBE—COULEUVRINE,

Before referred to as being described on page 117 of "No. IV," were tried during the latter part of 1886, and are reported to have reached a speed of slightly over 18 knots, but *not* over the measured bases.

ETOILE.

A small composite cruising gun-vessel, built at Rochefort dockyard, and completed during the past year, was tried in March, 1886, with the mean results of 389 I. H. P. and 10.4 knots speed. The principal dimensions are: Length, 149 feet 2 inches; beam 24 feet 7 inches; mean draught, 7 feet 10 inches; displacement, 448 tons. Armament, two 5.5-inch B. L. pivots, two 4-inch B. L. pivots, and two H. R. C. The single screw is driven by a horizontal compound 2-cylinder engine, for which the steam is supplied by two 2-furnace boilers. Sixty-six tons of coal may be carried, and a complement of 77 officers and men. The rig is barkentine, spreading 4,564 square feet of canvas. Cost, complete, is about $140,000.

ITALY.

VESSELS LAID DOWN.

SARDEGNA.

Battle ship, referred to on page 204 of "No. V" as having been ordered, has been laid down at Spezzia, and is now being built.

FIERAMOSCA.

Protected cruiser, referred to on the same page as having been ordered, has been laid down at Leghorn by Orlando Bros. Her dimensions are slightly different from those of the Etna (described on page 203 of "No. V"), with which she was classed, but in all other respects she is the same. The length is increased to 290 feet, the beam to 43 feet 5 inches, and the displacement to 3,745 tons.

ARCHIMÉDE—GALILEO.

Small cruisers, referred to on the same page, have been laid down at the Venice dockyard. They have single screws and are built throughout of steel; are 229 feet 7 inches long, 26 feet 3 inches beam, 10 feet 10 inches mean draught of water, and of 784 tons displacement. The armament will be four 4.72-inch Armstrong B. L., and a supply of rapid-fire or machine guns. Two torpedo tubes will be fitted. The engines are expected to develop 1,700 I. H. P. and a speed of 17 knots.

The Galileo was launched May 2, 1887.

VOLTURNO—CURTATONE.

Small, single-screw, cruisers, also referred to on the same page as having been ordered, have been laid down at the Venice dockyard. They are being built of steel throughout and are to be bark rigged. Their principal dimensions are: Length, 177 feet 1 inch; beam, 32 feet 7 inches; mean draught, 13 feet; displacement, 1,056 tons. The engines are 2-cylinder, horizontal compound, of 1,000 I. H. P., estimated; those of the former built by Hawthorne, and of the latter by Pattison & Co., of Naples. Their main battery will consist of three 4.72-inch B. L.

MONZAMBANO—MONTEBELLO.

Sister vessels to the torpedo cruisers Tripoli and Goito, described on page 204 of "No. V," have been laid down at Spezzia. These vessels will all have five launching tubes for torpedoes, two at the bow, fixed, and three training, one aft and one each side. They will be rigged with two pole masts and will carry crews of 100 officers and men. The armaments will be four 57-millimetre R. F., four 37-millimetre R. F., and three 37-millimetre R. C. The engines of the Monzambano and Montebello will be triple expansion, while those of the others are 2-cylinder compound, inclined. Six single-furnace locomotive boilers in three independent groups will furnish the steam.

CONFIENZA.

A small steel twin-screw cruiser, somewhat similar to the two just described but of slightly different dimensions, is to be built at Spezzia. The principal dimensions are: Length, 229 feet 7 inches; beam, 26 feet 4 inches; mean draught, 9 feet 6 inches; displacement, 770 tons. The armament will be four 4.72-inch B. L., together with rapid-fire and machine guns, and a supply of torpedoes dischargeable through five above-water tubes. The speed is estimated to be 17.5 knots, developed by engines of 2,800 I. H. P.

VESSELS LAUNCHED.

TRIPOLI.

Torpedo cruiser, described on page 204 of "No. V," and further described under the head Monzambano on the preceding page, was launched at Castellamare August 23, 1886.

It is claimed that she has realized a speed of 24 knots, and has maintained a mean speed of 23 knots for 50 miles.

The total cost of hull and machinery is about $340,000.

MISENO—PALINURO.

Small iron cruising gun-vessels, laid down at Castellamare in 1885 and launched in 1886, the former in July. Dimensions: Length, 138 feet 6 inches; beam, 25 feet; mean draught, 10 feet 11 inches; displacement, 548 tons; armament, two 4.72-inch

B. L. and two H. R. C. Vertical compound engines, driving one screw, are expected to develop 430 I. H. P. and a speed of 10 knots.

VESSELS PURCHASED.

DOGALI.

A small, twin-screw, lightly protected, steel cruiser. She was built at Elswick by Armstrong & Co., was purchased by Italy in January, 1887, and named as above.

In the construction of this vessel everything was sacrificed to engine power with the expectation of obtaining very great speed on comparatively small displacement, and, as far as the engines were concerned, the results were very satisfactory, though the speed realized was not quite up to what might have been expected with the great horse-power developed. The displacement is 2,000 tons, length, 250 feet, and beam, 37 feet. The engines were built by Hawthorne, and are of the triple-expansion type. On the first trials they developed 8,100 I. H. P. and a speed of 18.5 knots, as a mean of seven runs over the measured mile; the mean revolutions were 162. It is claimed that at a later trial the mean of four runs over the measured mile was at the rate of 19.13 knots per hour. On April 5, 1887, the official trial off the Tyne developed a mean of 7,600 I. H. P., with 154 revolutions. With this power the speed over the measured mile was 19.66 knots.

But a small crew can be carried, the quarters below deck being exceedingly cramped owing to the great proportion of space occupied by the machinery. To partially remedy this a high poop and forecastle have been built, the rail in the waist being low. Two very high oval smoke-pipes furnish draft to the four double-ended 6-furnace steel boilers. The designed armament is six 5-inch B. L., mounted on sponsons, two on the forecastle, two on the poop, and one each side in the waist. There is also a ram bow, fitted with a torpedo tube, and two masts with military tops. The cost is stated to be $735,000.

AMERICA.

In January, 1887, this fine passenger and mail steamer of the National Line was purchased by Italy to be incorporated into her war fleet as a torpedo-depot and transport vessel. She was built on the Clyde, by the Thomsons, entirely of steel, and was launched in 1884.

The principal dimensions are: Length, b. p., 430 feet; over all, 441 feet 8 inches; beam, 51 feet 3 inches; depth, 38 feet 5 inches; load draught forward 25 feet, aft 26 feet; gross tonnage, 5,528; displacement, 6,500 tons.

The engines, built by the same firm, drive a single screw of 22 feet diameter, 29 feet pitch, and are of the vertical compound three-cylinder type. They develop a maximum speed of 18½ knots, and can maintain a mean sea speed of 17 knots on a consumption of 216 tons of coal per diem. The average I. H. P. developed is 9,000. The bunker capacity is 1,550 tons of coal.

Steam is furnished by six steel double-ended cylindrical six-furnace boilers, and one single-ended of three furnaces. Two oval-shaped funnels supply the draft. The rig is that of a full brig.

The armament and complement of torpedoes and torpedo-boats has not been announced.

GERMANY.

NAVAL POLICY AND VESSELS PROPOSED.

The policy of the German Government is not to maintain a large cruising fleet abroad, but to provide chiefly in this respect for small flying and practice squadrons. It is necessary, however, that her coasts should be thoroughly well guarded, and for this reason much attention has been devoted to the development of the torpedo flotilla and to the acquirement of coast defense armor-clads.

It is proposed by the naval department to still further augment these two latter classes, and estimates have been made for the construction of six large armored gun vessels for the defense of the mouths of the Elbe, and four similar vessels for the defense of other assailable points on the coast. The estimated cost of these vessels is about $825,000 each, and it is proposed that the first six should be completed by the time the North Sea and Baltic ship-canal is open for traffic. The annual expenditure for new construction for the next five years is placed at $1,890,000.

Estimates have been made on the value of the fleet and its annual rate of depreciation, but on a less elaborate plan than the similar estimates, before described, made by the British admiralty.

Only the modern vessels are included in the estimate, and their present value is placed at $47,600,000. The assumption is made that the useful lifetime of an iron or steel ship is thirty years, and as all the vessels included in the estimated value are built of iron or steel and are assumed to be new at the present time, an annual expenditure of 3.3 per cent. of the present value is stated to be a fair amount to allow for the construction of new vessels in order to maintain the present fleet at its norma strength; that is, in figures, an annual expenditure of $1,575,000 for new construction.

VESSELS LAUNCHED.

EBER.

The cruiser described on page 206 of "No. V" as having been laid down in 1885 at the Dantzig dockyard, was launched February 15, 1887, and received the name of Eber.

GREIF.

The dispatch vessel described on page 205 of "No. V" as building at the Germania Works at Gaarden, near Kiel, was launched July 29, 1886, and named Greif. Her dimensions are somewhat different from those there given, and are as follows: Length, 317 feet 6 inches; beam, 32 feet; depth, 21 feet 6 inches; displacement, 2,000 tons. The armament will be two 4-inch B. L. and ten H. R. C. A speed of 19 knots is expected to be developed by the two sets of compound vertical 2-cylinder engines of 5,400 estimated I. H. P. driving twin screws. The steam is furnished by six 4-furnace cylindrical boilers. She will be schooner-rigged and will carry a crew of 130 officers and men.

STEAM TRIALS.

The full-power trial is to determine the horse-power developed and the rate of coal consumption. In some recent cases it has been required that the stipulated I. H. P. should be developed with the usual fire-room force of the ship. If additional men from the dockyard are sent on board for the trial they are merely to assist the crew, and not to do all the firing. To determine the speed is not the object of this trial, though it is not made if the force of the wind exceeds 4.

This trial lasts six hours. Previously the engines are put in the best possible condition, furnaces cleaned, and water in boilers changed if thought necessary. The coal is carefully weighed, and the fires left in the same condition at the end as at the beginning of the trial. The stop-valves are kept wide open, and the position of the expansion gear, and of all other valves in engine and boiler rooms, are changed as little as possible. Indicator diagrams are taken every quarter hour, and the data entered thereon.

After this six hours' trial the speed trials over the measured mile take place, the engines, &c., being put in the same condition as before. The force of the wind must not exceed 4. Four or six runs are made over the measured mile, with the engines making the same mean number of revolutions as were made on the six hours' trial. Two counters are used, one of which is going continually, the other being on deck, and thrown in and out of action when the ship comes on and leaves the mile. The mean number of revolutions is taken from the latter counter. The mean of the runs is taken as the maximum speed.

The progressive steam trials with natural draft and different numbers of boilers in use are then made over the measured base, which is usually 40 to 50 miles long with a turn. The ship is docked before trial to have her bottom cleaned, and the draught before and after trial is recorded, the mean being taken as the draught for the trial. The engines and boilers are managed by the engineer force of the ship. During each trial, indicator diagrams are taken every quarter hour, and the mean of the complete run is taken as the mean I. H. P. for that run. The speed is determined by observation of the marks and the elapsed time. The time occupied in turning is deducted from the time of the whole run. The openings of the valves and setting of the cut-off is not changed during the run, their position having been previously determined for the boiler pressure on the preliminary trial.

The results of each trial are tabulated, showing the speed, revolutions, boiler power, coal consumption, &c., and a copy given to the commanding officer of the ship.

ALEXANDRINE

A swift cruiser, corvette built, of iron and steel, sheathed and coppered, was launched February 7, 1885, at the Kiel dockyard, where she was laid down in July, 1881. She had a steam trial of twelve hours' duration October 13, 1886, and developed 2,400 I. H. P., and a mean speed of 15 knots, which were the results required. There was a heavy sea throughout the trial, and the wind blowing a gale.

The principal dimensions of the ship are: Length, 234 feet 6 inches; beam, 41 feet 6 inches; draught, 16 feet 6 inches forward, 18 feet aft; displacement, 2,370 tons; armament, twelve 5.9-inch (15-centimetre) B. L., two 3.4-inch (8.7-centimetre) B. L., one 3-inch B. L., four H. R. C., and a supply of Schwartzkopff torpedoes. She is bark rigged, and carries a crew of 267 officers and men.

The Arcona, laid down at Dantzig dockyard at the same time, and launched May 18, 1885, is a sister ship in all respects.

These vessels were partially described on page 119 of "No. IV."

RUSSIA.

VESSELS LAID DOWN.

NICHOLAS I—ALEXANDER II.

The vessel described on page 206 of "No. V" as having been laid down in November, 1885, by the Franco-Russian Company of St. Petersburg, was not laid down until July 23, 1886, and was named Nicholas I.

The other vessel referred to on the same page as being built at the Admiralty Works at St. Petersburg is named Alexander II. Similar in all respects, these two vessels are 327 feet long, 67 feet beam, 25 feet 6 inches mean draught of water, and displace 8,440 tons. They are built of iron and steel, are sheathed with wood and coppered, have strong ram bows, are brig rigged, and will carry complements of 570 men. The armor protection consists of a complete steel belt 9 feet wide and 14 to 6 inches thick, one 10-inch steel pear-shaped barbette tower forward, and a complete curved steel protective deck 3 inches thick. The battery proposed is two 12-inch B. L., four 9-inch B. L., eight 6-inch B. L., four 3.5-inch B. L., four 6-pounder R. F., and six H. R. C., though the main battery may be changed to two 14-inch B. L. and ten 6-inch B. L. The engines are of the vertical compound 3-cylinder type, and are estimated to develop 8,000 I. H. P. and a speed of 16 knots. Twelve cylindrical 4-furnace boilers will supply the steam.

PAMJATJ AZOWA.

The vessel referred to on page 206 of "No. V" as building at the Baltic Works near St. Petersburg is named as above, but is not similar to the two vessels just described, and was not laid down until July, 1886. She is an armored cruiser somewhat of the type of the British Impérieuse, with a partial armor belt and armored barbettes. The principal dimensions are: Length 377 feet 9 inches, beam 50 feet, displacement 6,000 tons. The engines are expected to develop 8,500 I. H. P. and a speed of 17 knots. The armament will be two 8-inch B. L., fourteen 6-inch B. L., and a supply of R. F. G. and H. R. C., together with Whitehead torpedoes.

URALETS—TERETS—KUBANETS—ZAPOROJETS—DONETS—CHERNOMORETS.

Heavy gun vessels for the Black Sea fleet, laid down in March, 1886, at Government dockyards, the first three at Sebastopol and the last three at Nicolaieff. They are of 1,224 tons displacement, 210 feet long, and 35 feet beam, and will carry batteries of two 8-inch B. L., one 6-inch B. L., two 6-pounder R. F., four H. R. C., and a supply of Whitehead torpedoes dischargeable through two tubes. The engines are compound and are estimated to develop 2,000 I. H. P. Those for the first three are building at the Motala Works, Sweden, and Napier, of Glasgow, is building the last three.

The Kubanets was launched April 9, 1887.

SAKEN.

A torpedo cruiser similar to the Iljin described on pages 88 and 207 of "No.V," was laid down at Nicolaieff on the Black Sea early in 1886.

VESSELS LAUNCHED.

CATHERINE II—TCHESME—SINOPE.

Partly described on page 120 of "No. IV." These additions to the Russian fleet are the most powerful battle ships that Government possesses. The first two were laid down in November, 1883, and were launched in May, 1886; the last was laid down in April, 1884, and was launched June 1, 1887. They are built of iron and steel, have heavy ram bows, are sheathed with wood and coppered, will carry complements of 500 men, and a coal supply of 870 tons. They are all being built on the Black Sea, for which fleet they are intended, the first at the Nicolaieff dockyard, and the last two at Sebastopol by the Russian Steam Navigation Company. Principal dimensions: Length, 339 feet; beam, 69 feet; mean draught, 26 feet 6 inches; displacement, 10,181 tons. Armament, six 12-inch B. L. mounted in pairs *en barbette*, in a large central pear-shaped redoubt on Moncrieff disappearing carriages, six 6-inch B. L. on gun-deck in broadside, one 6-inch B. L. shifting pivot aft on gun-deck, seven H. R. C., and a supply of Whitehead torpedoes, which may be discharged through seven tubes. The armor protection consists of a complete belt of compound armor 18 to 12 inches thick, and a complete steel protective deck 3 inches thick. The armor on the redoubt is 14 inches thick. The engines of the Catherine II were built at the Baltic Works at St. Petersburg, and are of the compound vertical 3-cylinder type, designed to develop 11,000 I. H. P. and a speed of 16 knots. The engines of the Tchesme are of the same type and were built in Belgium by Cockerill, while the Sinope's engines were built by Napier, at Glasgow, and are triple expansion, designed to develop 10,000 I. H. P. with natural draft, and 13,000 I. H. P. with forced draft. The boilers of all are cylindrical, 14 in number, with 3 furnaces in each. The cost of each vessel complete for sea will be about $4,500,000.

ADMIRAL KORNILOFF.

The large protected steel cruiser partially described on pages 206 and 207 of "No. V" as building at St. Nazaire, was launched April 9, 1887, and named the Admiral

Korniloff. The speed expected is 19 knots, developed by engines of 8,260 I. H. P., driving twin screws. The full bark rig will give sufficient sail power for cruising under canvas. The armament will be fourteen 6.3-inch (16-centimetre) B. L., four of which are mounted on sponsons giving bow and stern fire, six R. F. G., ten H. R. C., and a supply of Whitehead torpedoes will also be carried.

COREETS—MANCHOORIA.

Small cruisers of 1,213 tons displacement, 206 feet long, 35 feet beam, and 11 feet draught of water, were launched, the former at Stockholm, by Bergsund, September 4, 1886, and the latter at Copenhagen, by Burmeister and Wain, December 4, 1886. They have twin screws and engines designed to develop 2,000 I. H. P.

ILJIN.

Described on pages 88 and 207 of "No. V," was launched July 24, 1886.

After a series of experiments with a torpedo-boat it was decided to replace the single screw originally designed by twin screws. The armament has also been changed to seven Hotchkiss rapid-fire guns and twelve H. R. C. Twenty-one 14-inch Whitehead torpedoes will be carried.

The engines are triple-expansion, and were designed by Napier, but built at the Baltic Works. Steam is supplied by four boilers, two of which are of the locomotive type. The coal supply is 97 tons and the complement of officers and men 109.

On September 24, October 1, and October 4, 1886, a series of steam trials of this vessel were had off Cronstadt, with natural draft. The mean draught of the vessel was 9 feet 5½ inches; displacement 627 tons. (Normal, 9 feet and 600 tons.) The contract required 3,600 I. H. P. and a speed of 20 knots with 160 pounds of steam, and 360 revolutions of the engines when forced draft was used, and 17½ knots speed when under natural draft.

On this series, with natural draft only, the maximum results obtained were 2,100 I. H. P. and 17.225 knots speed, with 276 revolutions and 160 pounds of steam. Theoretically, this speed of the engines should have developed 19 knots speed.

During the month of October, 1886, it is claimed that 2,230 I. H. P. was developed with natural draft, and 3,550 I. H. P. with 350 revolutions when under forced draft. On one of the trials the maximum speed developed was 19.67 knots, and on a later trial 20.1 knots was reached.

The boilers and engines are reported to have worked well throughout the trial.

The vessel was found to be very handy and the steering gear most efficient. At 12 knots speed a complete circle of 2,000 feet diameter was made, with the helm hard over, in 4 minutes and 58 seconds.

ALEUTA.

A small torpedo transport, built at the Hyland Works of Christiania, Norway, in 1886, is of 811 tons displacement, 151 feet long, and 31 feet beam. The engines are designed to develop 760 I. H. P., and a speed of 12 knots is expected to be maintained. A light battery of rapid-fire and Hotchkiss R. C. will be mounted. The interior arrangements are designed solely for transporting torpedoes of different types, and high explosives.

SPAIN.

NAVAL POLICY AND VESSELS PROPOSED.

The scheme for rebuilding the Spanish navy was published over the signature of the Queen Regent, dated January 12, 1887, and designates the following types and number of vessels to be built, together with their estimated cost:

I. Eleven protected steel cruisers, eight of 3,200 tons displacement, and three of 4,500 tons; to carry 9.45-inch (24-centimetre), or 11-inch (28-centimetre) Hontoria B.

L. on central pivots, and smaller guns in broadside; also a complete armament of rapid-fire guns and mobile torpedoes. To be constructed on the cellular system, with double bottoms, and many W. T. compartments. The engines to be triple-expansion, driving twin-screws, and the speed to be 21 knots with forced draft, and 19 knots, at the least, with natural draft. The 3,200-ton vessels to cost $965,000 each, and the 4,500-ton vessels $1,351,000 each; total, $11,773,000.

II. Six steel torpedo-cruisers of 1,500 tons displacement, having triple-expansion engines and a speed of 23 knots with forced draft and 21 knots with natural draft; to be armed with 6.3-inch to 7-inch (16 to 18-centimetre) B. L. central pivots, and such smaller guns as it may be found possible to install in broadside; also rapid-fire guns and a supply of auto-mobile torpedoes. The construction to be cellular, with double bottoms and water-tight compartments. The cost to be $482,500 each; total, $2,895,000.

III. Four torpedo-cruisers of 1,100 tons displacement; cellular construction, double bottoms, and W. T. compartments; to have triple-expansion engines, and a speed of 18 to 21 knots per hour. The armament to consist of 5.5-inch to 6.3-inch (14 to 16-centimetre) B. L., and a supply of rapid-fire guns and auto-mobile torpedoes. To cost $386,000 each; total, $1,544,000.

IV. Twelve steel torpedo-gunboats, six of them of 600-tons displacement, and six of 350 tons, with a speed of 16 to 18 knots per hour. To cost, the larger type, $289,500 each, and the smaller, $193,000 each; total, $2,895,000.

V. Sixteen steel torpedo-gunboats of 200 to 250 tons displacement, and a speed of 14 to 16 knots per hour. To cost $144,750 each; total, $2,316,000.

VI. Ninety-six torpedo-boats of 100 to 120 tons displacement, a maximum speed of 24 knots per hour, and coal endurance for 1,500 miles. To cost $115,800 each; total, $11,116,800.

VII. Forty-two torpedo-boats of 60 to 70 tons displacement. To cost $77,200 each; total, $3,242,400.

VIII. One transport of 3,000 tons displacement, fitted as a floating arsenal or machine-shop. Cost, $482,500.

IX. Twenty steam-launches of 30 to 35 tons displacement, built of steel on the life-boat system, with three water-tight compartments; triple-expansion engines, and a speed of 12 to 14 knots per hour. To cost $19,300 each; total, $386,000.

Grand total for new vessels	$36,650,700
For completing the vessels now building: Pelayo, Reina Regente, Isla de Cuba, Isla de Luzon, Destructor, Alfonso XII, Reina Cristina, Reina Mercedes, Conde de Venadito, Infanta Isabel, Don Juan de Austria, Isabel II, Cristobal Colon, Don Antonio de Ulloa, and four first-class torpedo-boats	4,361,800
For improving the arsenals	1,930,000
For submarine defenses	482,500
Total	43,425,000

The new fleet thus authorized—building and to be built—will be composed of:

Armor-clad	1
First-class cruisers	12
Second and third-class cruisers	13
Torpedo-gunboats	32
First-class torpedo-boats	100
Second-class torpedo-boats	50
Steam-launches	20
Arsenal transport	1
Total	229

The fleet now existing, efficient for active service, consists of:

Armor-clads	2
First-class cruisers	6
Vessels of the second and third-classes	16
Smaller vessels	37
Total	61

VESSELS LAUNCHED.

PELAYO.

The unnamed battle-ship described on pages 207 and 208, of "No. V," was launched February 5, 1887, and named Pelayo. The description there given is correct, except that the armor on the barbette towers is 11.8 inches steel; the protective deck is 3.5 inches thick; 700 tons of coal will be carried, sufficient for 885 miles at 15 knots, and 2,340 miles at 13 knots; seven torpedo-tubes are fitted, and the light guns consist of twelve 4.72-inch B. L. in broadside, and one 6.3-inch B. L. in bow. The cost complete is said to be $3,520,000.

REINA REGENTE.

This powerful protected steel cruiser was launched from the yard of the Thomsons, at Clydebank, February 24, 1887, where her keel was laid June 11, 1886. The description given on pages 83, 208, and 209, of "No. V," of a fast cruiser designed for Spain needs correction; it was compiled early in May, 1886, from the most authentic professional London journals, but did not properly describe the vessel, which underwent considerable change in design and dimensions after the original plans were submitted in competition.

The design finally approved, which was submitted by the Thomsons, was for the vessel lately named the Reina Regente, and of the following principal dimensions: Length, on L. W. L., 320 feet; over all, 335; beam, 50 feet 7 inches; depth, 32 feet 8 inches; draught, mean, 20 feet; displacement, 4,800 tons. With her full capacity of coal and stores on board the displacement is increased to 5,600 tons, and the draught correspondingly.

The general appearance is somewhat similar to that of the Atlanta or Esmeralda type; a high superstructure occupying the waist, while the forecastle and quarter-deck are low. The armament will consist of four 9.45-inch (24-centimetre) Hontoria B. L. pivots, mounted, two forward and two abaft the superstructure, on platforms raised about 4 feet above the deck; six 4.72-inch (12-centimetre) Hontoria B. L., two mounted each side on sponsons, and one each side in recessed ports; eight 6-pounder H. R. F., and six H. R. C. Ten Schwartzkopff torpedoes will also be carried, five above-water tubes being fitted for launching them, two in the bow, one in the stern, and one each side. All the heavy guns will be protected by steel hoods or shields. The ship's protection consists of a complete steel deck, curving from 6 feet below the water-line to a horizontal about the height of the water-line. This horizontal part is about one-third the width of the ship and is 3 inches thick over the engines and boiler space, and 1 inch thick over the remainder. The inclined or curved portions are 4¾ inches thick. The space between this deck and the deck above is filled with coal over the machinery space. To assist in excluding water when pierced at or below the W. L. a complete belt of cellulose extends around the ship, about the height of the water-line, inside the inner skin.

The motive power consists of two sets of triple-expansion engines, driving twin-screws, and designed to develop 7,000 I. H. P. and a speed of 17.5 knots with natural draft, and 12,000 I. H. P. and a speed of 20.5 knots with forced draft. The two masts will carry military tops, and will also be fitted with a fore-and-aft rig. Three hundred officers and men will constitute the crew. The coal supply will be 1,200 tons, sufficient to steam 13,000 miles at moderate speed. The cost of hull and machinery, without battery or equipment, is $1,180,000.

ISABEL II—CRISTOBAL COLON—DON ANTONIO ULLOA—DON JUAN DE AUSTRIA.

Sisters to the cruiser Infanta Isabel, described on page 208, of "No. V." The first was launched in May, 1886, from the Ferrol dockyard, the others on January 23, 1887. The Colon and Ulloa were built at Carraca and the Don Juan de Austria at Cartegena. They were all laid down in 1883.

The cost of the hull and machinery of these vessels is about $225,000 each.

ISLA DE LUZON—ISLA DE CUBA.

Small steel cruisers of high speed, ordered in January, 1886, from the firm of Armstrong, Mitchell & Co., of Elswick, laid down the following month, and launched, the first in November, 1886, and the second in December of the same year. They are schooner-rigged with military tops, have a partial protective deck, long projecting ram bows, a high top-gallant forecastle, and a raised barbette platform near the stern; and are fitted with two torpedo-tubes.

The principal dimensions are: Length, 200 feet; beam, 29 feet 6 inches; mean draught, 11 feet 10 inches; displacement, 1,050 tons. Armament, six 4.72-inch (12-centimetre) B. L., and four H. R. C. The motive power will consist of two sets of triple-expansion engines, designed to develop 2,200 I. H. P. and a speed of 16 knots.

LEYTE.

A small cruising gun vessel for service in the Philippine Islands. She is being built by subscriptions from the inhabitants of that archipelago by the Whampoa Dock Company, of Hong-Kong, where she was laid down early in 1886, and launched in February, 1887. She will be a modern vessel in all respects, being constructed of steel, divided into numerous water-tight compartments, fitted with a torpedo-tube in the bow, and furnished with electric lighting throughout. She will have a ram bow, a schooner-rig with military tops, and will be of the following dimensions: Length, 161 feet; beam, 23 feet 6 inches; draught, 10 feet. Armament, three 4.72-inch (12-centimetre) B. L., one in bow, one each side on sponsons, two H. R. C., and two Nordenfelt 1-inch.

The engines will be of the vertical compound type, driving twin screws, and are estimated to develop 14 knots speed. The coal capacity will be 90 tons, and the complement 113 officers and men.

STEAM TRIALS.

DESTRUCTOR.

Partially described on page 208 of "No. V." The chief elements of the design of this vessel, as she was finally built, are as follows:

Length, b. p., 192 feet 6 inches; beam, 25 feet; depth at centre, 13 feet; normal mean draught, 6 feet 3 inches; mean load draught, 7 feet; normal displacement, 350 tons; deep-load displacement, 458 tons. The armament consists of one 4-inch B. L. pivot, four 6-pounder R. F. G., two 47^{mm} H. R. C., and five torpedo-tubes—two in the bow, one in the stern, and two on deck on a turn-table. Six 15-foot torpedoes will be carried. The motive power consists of two sets of vertical triple-expansion engines driving twin screws, the cylinders being 42, 27, and 18½ inches diameter, and the stroke 4 feet. Four cylindrical boilers supply the steam. The hull is divided into 39 W. T. compartments, each set of engines and each boiler being in a separate compartment. There is complete coal protection around the machinery space, and the bunker bulkheads are ⅜-inch steel. Forward of the boilers and magazines a curved steel bulkhead, 1½ inch thick, gives protection from raking fire. The normal coal supply is 45 tons, and the total bunker capacity 110 tons. With the former amount a distance of 2,050 knots at 10 knots per hour can be covered, and with the latter amount at the same speed 5,500. The complement of officers and men is placed at forty-five.

Launched on July 29, 1886, this vessel has had a very successful series of trials. Although of such small size she is provided with engines of 4,000 estimated I. H. P.; has proven herself a good sea boat, able to make a long passage at high speed, and is the fastest vessel now afloat, exclusive of torpedo-boats.

To facilitate manœuvring she is cut away considerably at each end, and is also fitted with an auxiliary bow rudder. The three masts have a fore-and-aft rig and are hinged to lower on deck.

The first trials were made by the contractor the last week in November, 1886, during two days, when the maximum speed attained was 23¾ knots. On December 13, 1886, a series of trials was had with all weights on board, except that the coal was for 1,800 miles at 11½ knots, the vessel displacing 385 tons. The trials were to consist of three runs over the measured mile; then three hours continuous run at full speed, followed by three more runs over the measured mile. The results were all satisfactory. The mean speed for three hours on the first trial was 22.56 knots; revolutions, 292; I. H. P., 3,784 with forced-draft pressure equivalet to 2 inches water. On the second trial the results were: speed, 22.68 knots; 292.3 revolutions; 3,829 I. H. P. At her deep-load displacement of 458 tons the maximum speed was 20.2 knots. By running 135 knots her coal-endurance was determined to be 5,100 miles at 11½ knots, and 700 miles at full speed. In a heavy sea 22 knots was made for four hours.

The turning trials were also highly satisfactory, a complete circle being made in 1¾ minutes, with a diameter of slightly less than three lengths of the vessel.

In January, 1887, she crossed the Bay of Biscay from Falmouth to Muros in 24 hours, at a mean speed of 21 knots, the distance being 495 knots. The wind was southeast, force 4 to 6. The cost complete for sea is about $245,000.

INFANTA ISABEL.

This light unprotected cruiser, previously described on page 208 of "No. V," had her official steam trials February 1, 1887, off Cadiz, with very satisfactory results. A mean speed of 15 knots was realized on the trial, which was equal to the estimated maximum speed.

PORTUGAL.

VESSELS LAID DOWN.

DIEGO CAM—ZAMBEZI.

Small single-screw composite cruisers of 590 tons displacement, building at the Lisbon dockyard. They are schooner-rigged, carry crews of 107 officers and men, a battery of two 6-inch Armstrong B. L., and a coal supply of 80 tons. Their principal dimensions are: Length, 143 feet; beam, 26 feet; mean draught, 10 feet 10 inches, and are designed to have a speed of 9 knots, developed by a single compound engine of 400 I. H. P.

VESSELS LAUNCHED.

CACONGO—MASSABI.

Small steel single-screw gunboats, designed for service on the African coast, and built by Laird, of Birkenhead. They were both launched during the year, the first on June 19, 1886. Their dimensions are: Length, 120 feet; beam, 19 feet 6 inches; depth, 8 feet 6 inches; displacement, 220 tons; armament, two 3-inch rapid-fire guns on the spar-deck. The speed is 11 knots, developed by single compound engines of 450 I. H. P.

AUSTRIA.

VESSELS LAID DOWN.

METEOR.

There was laid down at Pola, by the Austrian Government, during 1886, a torpedo cruiser, similar to the Panther and Leopard, described on pages 86, 138, and 206 of "No. V." She has been named Meteor, and will be launched during the year. The total cost is estimated to be about $410,000.

TIGER.

A protected cruiser of the latest type; was laid down early in 1887. She is to be built of steel, of about 3,800 tons displacement, and is to cost, exclusive of armament and equipment, about $800,000.

VESSELS LAUNCHED.

KRONPRINZESSIN ERZHERZOGIN STEFANIE.

This coast-defense armor-clad is completing at San Rocco, near Trieste, and takes the place of the old broadside iron-clad Erzherzog Ferdinand Max. She was launched April 14, 1887, having been laid down in April, 1884. Built of steel throughout, her principal dimensions are: Length, b. p., 278 feet 10 inches; beam, 55 feet 9 inches; draught, 21 feet 7 inches; displacement, 5,150 tons. The armor protection consists of a complete steel belt 9 inches thick, an oval-shaped steel barbette tower forward 8 inches thick, a complete steel protective deck over top of the belt, and steel shields for all the guns. The armament will consist of two 12-inch (30.5-centimetre) Krupp B. L. in the barbette, six 5.9-inch (15-centimetre) Krupp B. L. in broadside, six Palmcrantz heavy machine-guns, and a supply of Whitehead torpedoes. The engines have an estimated I. H. P. of 6,500, and will drive twin screws. Two masts with military tops will be fitted. The coal supply will be 400 tons, and the speed expected is 15 knots. The estimated total cost of the vessel is about $1,500,000.

KRONPRINZ ERZHERZOG RUDOLF.

This armor-clad is also a coast-defense vessel, but of a larger type, and is building at the Pola dockyard to replace the old broadside iron-clad Salamander. She is built of steel, was laid down in 1884, and is of the following dimensions: Length, 295 feet 2 inches; beam, 62 feet 4 inches; mean draught, 25 feet 3 inches; displacement, 6,900 tons. The armor protection consists of a partial-steel belt 12 inches thick with bulkheads, two oval-shaped barbette towers clad with steel 11 inches thick, and a complete steel protective deck of a maximum thickness of 2¾ inches. Steel shields protect all guns. The engines, of 6,500 I. H. P., estimated, will drive twin screws, and a speed of 14 knots is expected. The armament will consist of three 12-inch (30.5-centimetre) Krupp B. L. in the barbette, six 3.5-inch (9-centimetre) Uchatius B. L. in broadside, six Palmcrantz heavy machine-guns, and a supply of Whitehead torpedoes. But one mast with a military top will be fitted. The coal supply will be 600 tons. The cost is estimated to be about $1,550,000.

REGULATIONS GOVERNING STEAM TRIALS.

The ship and engines being ready for the trials over the measured mile, the commanding officer brings the ship to the starting point, at the same time signaling the engine-room "full power." When the half-mile post is passed, the engine-room force is notified, and as soon as the mile point is passed, the signal "half-power" is made.

Before bringing the ship to the mile again, care is taken that the steam is at full pressure. The run over the mile is then made as before. Three double runs are made, during each of which a series of indicator diagrams is taken and the number of the run entered thereon. Any change of course during a run renders the value of the run null, and another run in the same direction has to be made. During the runs the stop-valves and throttle-valves are kept wide open, and the cut-offs so arranged as to give the maximum power.

TURKEY.

VESSELS ORDERED OR LAID DOWN.

A small composite cruiser of 670 tons displacement was ordered in October, 1886, to be laid down at the dockyard at Constantinople, to be of the following dimensions: Length, 165 feet; beam, 29 feet; mean draught, 10 feet 9 inches; to be armed with one 4-inch B. L. pivot; four 4-inch B. L. in broadside; two Nordenfelt and two Gardner machine guns; and to have a speed of 15 knots, developed by engines of 1,000 I. H. P. The rig is to be three-masted schooner.

At the same place in July, 1886, a vessel of the "torpedo catcher" type was ordered to be laid down with the following principal dimensions: Length, 200 feet; beam, 23 feet; draught, 8 feet; displacement, 450 tons. She is to have a speed of 21 knots, developed by triple-expansion engines of 2,700 I. H. P., and to carry an armament of one 4-inch B. L. central pivot forward, six H. R. C. in broadside, and four tubes for Whitehead torpedoes, one in bow, one in stern, and one each side.

In October, 1886, a contract was signed with a German firm to build three torpedo cruisers; one to be 229 feet 7 inches long, and to have a speed of 25 knots; one 196 feet 10 inches long, and 23 knots speed; and one, 147 feet 7 inches long and 20 knots speed. All to carry armaments of Hotchkiss guns, and Schwartzkopff torpedoes.

Two single-screw composite cruisers are being pushed to completion at the Constantinople dockyard, where they were laid down in 1881, since which time the original plans have been much altered. The largest of these vessels is 1,950 tons displacement, 226 feet long, 37 feet beam, and 21 feet draught of water aft. Her armament is to be two 6.7-inch (17-centimetre) B. L. pivots, six 4.72-inch (12-centimetre) B. L. in broadside, and a supply of machine guns. The engines are estimated to develop 2,500 I. H. P., and a speed of 15 knots; 250 tons of coal will be carried.

The smaller vessel is 210 feet long, 37 feet beam, 15 feet draught of water aft, and displaces 1,660 tons. The estimated I. H. P. is 2,000, and the speed expected is 14 knots.

HOLLAND.

VESSELS LAUNCHED.

JOHAN WILLEM FRISO.

The last of six large cruisers of which the others are the Atjeh, Tromp, Koningin Emma der Nederlanden, De Ruyter, and Van Speyk. The Atjeh was laid down in 1875 and launched in 1876; and the Friso was laid down in 1883 and launched during 1886. All these vessels are sister ships, built of iron and steel, sheathed with wood to 4 feet above the W. L., and coppered; are full ship-rigged, spreading 19,050 square feet of canvas, and were all built at the Government dockyard at Amsterdam. They are of 3,400 tons displacement, and the following principal dimensions: Length, 262 feet 5 inches; beam, 39 feet 4 inches; mean draught, 18 feet 4 inches. Their armaments are six 6.7-inch (17-centimetre) Krupp B. L; one bow and one stern pivot, the others in broadside; eight 4.72-inch (12-centimetre) Krupp B. L. in broadside; six 37-millimetre H. R. C., and a supply of Whitehead torpedoes. The engines drive single screws, and have an estimated I. H. P. of 3,000, which has been slightly exceeded by some and not attained by others. The speeds vary from 14.1 knots to 14.7 knots, the estimate being 14.5 knots. The steam is supplied by four double-ended cylindrical, 6-furnaceboilers. The coal supply is 400 tons, sufficient for six and three-quarter days' steaming at full speed, or thirteen days at 10 knots. The ammunition supply is 115 rounds for each large gun. A crew of 340 officers and men is allowed.

DENMARK.

VESSELS LAID DOWN.

VALKYRIEN.

On November 1, 1886, this steel cruiser of modern design was laid down at the Government dockyard at Copenhagen. She has a ram bow and the following principal dimensions: Length, 268 feet; beam, 43 feet 6 inches; mean draught, 18 feet; displacement, 2,900 tons. The armament will be: Two 8.3-inch (21-centimetre) Krupp B. L.; six 5.9-inch (15-centimetre) of the same type; ten H. R. C., and a supply of Whitehead torpedoes, dischargeable through five tubes. The engines driving twin screws are expected to develop 5,000 I. H. P. and a speed of 17 knots. The coal supply will be 450 tons.

STEAM TRIALS.

IVER HVITFELDT.

This small armor-clad, described on page 213 of "No. V" had her steam trials off Copenhagen early in May, 1887, when the maximum speed developed was 15.6 knots.

SWEDEN.

STEAM TRIALS.

SVEA.

The armored coast-defense vessel described on pages 212 and 213 of "No. V" had her steam trials in July, 1886, and developed a mean speed of 15.45 knots over the measured base. The estimated speed was 14 knots.

NORWAY.

VESSELS LAID DOWN.

TYR.

A small gun vessel, similar to the Gor, described on page 213 of "No. V," was laid down at the Government dockyard during the year.

CHINA.

VESSELS ORDERED OR LAID DOWN.

In April, 1886, the Chinese Government ordered of the Vulcan Company, Stettin, two heavy coast-defense armor-clads of 7,000 tons displacement and 6,000 I. H. P. each.

During the same year an armored gun vessel was laid down at the Foochow dockyard.

Several small gunboats of the Kuang-Chen type (hereafter described) were also ordered to be laid down at the Whampoa dockyard.

VESSELS LAUNCHED.

CHIH-YUEN—CHING-YUAN.

High-powered steel cruisers, somewhat similar to the Baltimore in general arrangements, but much smaller, with protective decks, 4 inches on the slope, 2 inches on the crown, laid down in October, 1885, at the Elswick Works of Armstrong, Mitchell & Co., and launched, the first September 29, 1886, and the second December 14, 1886. They are of 2,300 tons displacement, 250 feet long, and 38 feet beam, and are similar in all respects. The armament will consist of two 8-inch B. L. forward, one 8-inch B. L. aft, and light guns in broadside. A secondary battery of rapid-fire and machine guns and a supply of Whitehead torpedoes will be carried.

The estimated speed is 18 knots, attained by two sets of triple-expansion engines, driving twin screws, and developing collectively 5,500 I. H. P.

KING-QUEN—LAI YUEN.

Two small, partially belted, barbette vessels intended for coast defense, but capable of making extended passages at sea, laid down in 1885 by the Vulcan Company, of Stettin, and launched, the first January 3, 1887, the second March 25, 1887.

The armor protection is compound and consists of a belt in wake of the engine and boiler space from 2 feet above the W. L. to 4 feet below, and 9½ to 5¼ inches thick. This belt is terminated by transverse bulkheads 7.9 inches thick. The under-water body is protected by a steel deck 1½ inches thick over top of belt and 3 inches thick, sloping to bow and stern, forward and abaft the belt. The one circular barbette tower is placed forward and is protected by 8 inches of compound armor; a strong steel shield extends over this barbette. A conning tower abaft and above the barbette is protected by 6-inch armor. The hull has a double bottom for two-thirds of its length and is divided into sixty-six water-tight compartments. Forward and abaft the belt the space between the protective deck and the deck above is divided into water-tight compartments, of which the outer tier is packed with cork. The armament will consist of two 8.27-inch (21-centimetre) Krupp B. L. 35 calibres long, mounted on a turn-table in the barbette; two 5.9-inch (15-centimetre) similar guns on the upper deck in six recessed ports with fore and aft fire; two 47-milimetre R. F. G.; five 37 millimetre H. R. C., four on the rail and one in the military top of the one steel mast, and a supply of Schwartzkopff torpedoes, dischargeable through four tubes, three above and one in the bow below the W. L. The principal dimensions are: Length, 270 feet 4 inches; beam, 39 feet 4 inches; depth, 25 feet 4 inches; draught aft, 16 feet 9 inches; displacement, 2,900 tons. The motive power is two sets of triple expansion engines driving twin screws, and required to develop 3,400 I. H. P. and a speed of 15.5 knots with natural draft, and 16.5 knots with forced draft. Steam is supplied by four cylindrical steel boilers. The supply of coal will be 325 tons; of provisions, sufficient for thirty days for the crew of 180 men; and of ammunition, 50 rounds for the large guns and 1,000 rounds for each gun of the secondary battery.

FEE-CHEN.

A small steel cruiser built by Doxford, of Sunderland, England, was launched April 20, 1887. She is to carry an armament of two 6-inch Armstrong B. L. and four light guns, and is to be fitted in addition as a cable steamer. The engines are triple expansion, cylinders 52 inches, 31½ inches, and 19½ inches, and are expected to develop 13 knots.

KUANG-CHEN—KUANG-HENG—KUANG-HUAN—KUANG-LI.

Small gunboats for the province of Canton, laid down at the Whampoa dockyard in 1885, and all launched and completed in 1886. They are similar in all respects, and are of the following principal dimensions: Length, 110 feet 10 inches; beam, 18 feet; depth, 7 feet 10 inches; draught aft, 7 feet 2 inches. Their armaments are one 5.9-inch 4½-ton Krupp B. L. mounted forward, one smaller Krupp B. L. mounted aft, and three Nordenfelt guns, one in top, and one each side, all protected by steel shields.

The engines are 78 I. H. P. and produce a speed of 7 to 8 knots. The cost of hull and engine is about $38,000 each.

JAPAN.

VESSELS ORDERED OR LAID DOWN.

In January, 1887, the Japanese Government ordered from the Société des Forges et Chantiers de la Méditerranée two coast-defense vessels, to be built on the plans of M. Bertin, constructing engineer of the Japanese navy.

They are to be built entirely of steel, on the cellular plan, with two longitudinal and twelve transverse bulkheads. Their principal dimensions are: Length, b. p., 295 feet 2 inches; beam, 50 feet 6 inches; depth, 34 feet 9 inches; draught aft, 21 feet 2 inches; displacement, 4,140 tons. The armament proposed is one 12.6 inch (32-centimetre) B. L., eleven 4.72-inch (12-centimetre) B. L., six R. F. G., twelve H. R. C., and four torpedo tubes, one in the bow, one in the stern, and one each broadside. Two independent triple-expansion engines, driving twin screws, and required to develop 5,400 I. H. P. with forced draft, and 3,400 I. H. P. with natural draft, supplied with steam by six 3-furnace boilers in two groups, furnish the motive power. The estimated maximum speed is 16 knots. A heavy protective steel deck, and a complete surrounding arrangement of coal-bunkers, protect the engine and boiler space, magazines, &c. The complement of officers and men will number 400.

In March, 1887, a small armored gun vessel, designed by the same official, was laid down at the Ishikawa-Shima dockyard, Japan. The displacement is 750 tons; length, 150 feet, and beam, 25 feet.

MAYA.

A twin screw, composite built gun vessel of 614 tons displacement, launched at Government dockyard of Onohama, near Kobe, August 18, 1886. She is of the following dimensions: Length, 154 feet 3 inches; beam, 26 feet 11 inches; mean draught, 9 feet 3 inches; displacement, 614 tons, and is expected to have a speed of 13 knots. The armament will be one 9.45-inch Krupp B. L. mounted forward, one 5.5-inch Krupp B. L. mounted aft, and two Nordenfelt guns in the waist.

STEAM TRIALS.

UNEBI.

This fine, protected cruiser, described on pages 210 and 211 of "No. V," sailed from France in November, 1886, for Japan, in charge of a French crew of 78 men. She left Singapore for Yokohama on December 3, 1886, and has never been seen or heard of since. She is said to have been top-heavy and to have rolled in a very dangerous manner in a sea-way.

In September, 1886, she had a very successful series of steam trials off Havre, maintaining an average speed of 18.5 knots during four runs over the the measured base, two in one direction and two in opposite. This exceeded by one knot the speed required by the contract. The I. H. P. developed with forced draft was 7,000. The cost of this vessel, exclusive of her armament, was $1,160,000.

HAYTI.

TOUSSAINT L'OUVERTURE.

In 1885 the Haytian Government desiring the possession of an efficient cruising gun-vessel of modern type, invited proposals from French builders to construct a vessel of 500 tons displacement, sufficiently rigged for sailing; to have a minimum speed of 12 knots; to be fitted with simple and strong propelling machinery; and to carry three guns.

The Société des Forges et Chantiers de la Méditerranée received the contract, and in March, 1886, the vessel was launched at their yard in Havre. She was built, armed, and equipped at the same place, and was turned over by the contractors, complete in every respect, in ten months from the signing of the contract.

She is built of steel, has a ram bow, is full brig-rigged, spreading 5,380 square feet of canvas, has a flush spar deck, and carries one 6.3-inch (16-centimetre) B. L. on a platform in the bow, two 4.72-inch (12-centimetre) B. L. on sponsons, one each side, just abaft the fore rigging, all fitted with steel shields, also several Nordenfelt guns. Eighty rounds of ammunition for each great gun will be carried. The principal dimensions are: Length, b. p., 164 feet; beam, 24 feet 7 inches; draught aft, 10 feet 8 inches; displacement, 500 tons. The engines are of the vertical compound type, drive a single screw, and develop 800 I. H. P. and a speed of 13.5 knots. Steam is supplied by two 2-furnace cylindrical boilers. The coal capacity is 120 tons, sufficient to cover 3,000 knots at 10 knots per hour. Steam steering gear, steam winches, and a steam launch are furnished. The vessel handles well, describing a complete circle of 700 feet diameter in four minutes. She is also said to behave well in a sea-way, ship no water, and roll but little.

A peculiar feature in the armament of this vessel may be noted in the gun-carriages. These permit a train of the 6-inch gun of 236°, with elevation of 28° and depression of 7°; while the broadside guns have a train of 165°, an elevation of 28°, and a depression of 3°.

CHILI.

VESSELS ORDERED.

In November, 1886, the Chilian Government ordered, in England, a powerful, protected, steel cruiser of 4,500 tons displacement and 19 knots speed, to be armed with two 10-inch 28-ton Armstrong B. L., one 8-inch 14-ton Armstrong B. L., two 6-inch 5-ton Armstrong, four 6-pounder rapid-fire guns, eight H. R. C., and a supply of Whitehead torpedoes, which may be discharged through eight tubes. The cost to be about $1,500,000.

J. C. COLWELL,
Lieutenant, U. S. N.

SPECIAL REGULATIONS IN FOREIGN NAVIES RELATIVE TO THE CARE AND PRESERVATION OF IRON AND STEEL SHIPS.

The British Admiralty Instructions contain the following:

The captain of an iron ship will ascertain the nature of the anti-fouling substance applied to different parts of the ship, and demand the necessary quantity to keep the iron in proper condition.

He will frequently ascertain the condition of the bottom and see that it is cleaned and coated whenever necessary, and that no copper is allowed to be in contact with iron.

The unsheathed outer bottom must be sighted at least once a year and recoated if necessary.

If any defects are discovered at any time they must be remedied immediately.

Gun metal propellers must be coated with the same composition as that on the bottom, and also have zinc protectors.

Iron frames and other structural iron work must be frequently examined, and when necessary cleaned and painted. Rust must be removed by hammering and scraping before painting.

Whitewash must not be used in any case on any parts of iron frames, outside plating, lower parts of bulkheads, inside plating, or other works in the hold; nor on any other iron work, unless well coated with paint.

No oily or greasy matter must be allowed to accumulate on the water-line, as it fosters growth of sea weed.

The engineer and carpenter must carefully inspect every accessible part of outer skin, ribs, frames, and inner skin during the first week in each quarter, and report the condition of the compartments.

The captain will be informed of all inaccessible parts of the ship, and of the means used for their preservation, when the ship is first commissioned.

The following instructions are given for closing water-tight doors and valves:

I. The signal for closing water-tight doors and valves is to be given in all vessels by continuous, sharp, short blasts on the fog-horn.

II. A fog-horn is to be kept ready for use at a moment's notice, both day and night, in all vessels and in such a place as to be distinctly heard in all parts of the vessel. In some vessels more than one fog-horn may be necessary.

III. In a fog, or in action, some water-tight doors, such as magazine doors, engine-room communications, &c., must be kept open, for which cases special means must be provided to convey orders to close these doors when the danger of collision is imminent.

Crews must be constantly exercised in closing water-tight doors. Men must be detailed who, on the sound of the fog-horn, will proceed with all speed to close the water-tight doors assigned to them. This order is peremptory, and the captain will see that a sufficient number of men are detailed for this purpose.

The German navy regulations and dockyard orders direct the following measures to be taken:

Ships in reserve.—Iron ships must not be moored near ships with copper bottoms, especially if the anti-fouling composition on the former is imperfect; and if this cannot be avoided, contact of the two metals must be carefully prevented. Such ships must not be moored to the same buoys, because their chains would form conductors to the different metals.

The double bottoms, wing passages, holds, and the ventilating and drainage systems must be kept clean and dry. Limbers must be examined once every month and all interior plating must be kept dry. Rudders of iron ships must be examined and turned twice every week, and the fact of this examination must be noted in the log.

Iron ships must, as a rule, be docked once every year, to clean bottom and renew paint. Double bottoms must be thoroughly cleaned and repainted every two or three years.

Ships in commission.—Commanding officers of iron ships must take advantage of every opportunity to examine the bottom. Copper in contact with iron must be strictly guarded against, especially in the immersed portions.

In ships with water-tight bulkheads they must periodically ascertain if orders to close compartments are strictly obeyed. All openings in these bulkheads must be closed by signal, and the time required to do so must be entered in the log. In the following cases the signal to close compartments must always be given either by the commanding officer or the officer of the deck :

(1) Whenever ship is cleared for action.
(2) Whenever it begins to be foggy.
(3) Whenever the ship touches bottom.
(4) In danger of a collision.

The French regulations are not as explicit in detail. In French ships all water-tight doors must be worked every Monday. All these doors and openings must be closed when exposed to torpedo attacks and in action. The engineer has charge of all such openings in compartments of engine and fire room, while the officer of the powder division has charge of the remainder.

MERCHANT VESSELS FOR WAR PURPOSES.

During the threatened war with Russia in 1885, the British admiralty found it necessary to expend enormous sums to engage the services of the fastest and most powerful merchant steamers as cruisers. Many of the vessels engaged never left port, and there was a long delay in getting the guns and fittings into the Oregon, the only one of those hired which was thoroughly equipped.

The secretary of the admiralty announces the proposed method for utilizing merchant vessels as cruisers, in a letter to the secretary of the British treasury, dated February 2, 1887, to the following effect:

That the experience derived from the events of 1885 has led the British admiralty to believe that true economy and real efficiency would be best promoted by securing, in times of peace, the fastest and most serviceable mercantile vessels for service in case of war. It will be remembered that in 1885 a sum approximating to £600,000 ($2,919,900) was expended in retaining the services of several fast merchant steamers, so as to prevent their being available for the service of any power inimical to the interests of the United Kingdom. Had arrangements existed similar to those now contemplated, it is believed that a considerable portion of this expenditure would have been averted, and a degree of confidence felt by the nation on which it is very difficult to place any money value.

Their lordships consider that subventions or annual payments for pre-emption in the use or purchase of these steamers should only be made with those vessels already existing which have an exceptionally high sea-going speed, or for vessels which may be built possessing great speed and adaptable in their construction as armed cruisers.

The admiralty consider that no vessel of less speed than 17 or 18 knots at sea would fully meet the object in view, and that existing vessels, even with this speed, but which have not been built specially to admiralty designs, would not be so valuable to the country as vessels which meet these requirements. The trades which can, from a mercantile aspect, support vessels of the type and character that the admiralty desire to see included in the reserve fleet of the navy are very limited. Such steamers are only likely to find a profitable mercantile employment in the mail and passenger service, particularly in that to America. Vessels constructed to meet admiralty designs will be at a disadvantage in respect to their cargo-carrying powers, and therefore it would be a distinct advantage to the country if every reasonable encouragement were given to ship owners to build and maintain this description of steamer in the trades that may be expected to support them. The retention of a fleet of "royal naval reserve cruisers" would be obviously of great national advantage. In a pecuniary sense they would serve to limit the necessity for the construction of fast war vessels to protect the commerce of the country. Not only would the nation be a pecuniary gainer in respect to the first cost of such vessels, but their annual maintenance, which amounts to a large sum, would be saved were such vessels maintained, whilst not required for admiralty purposes, in mercantile trading.

Their lordships have not formed a definite view as to the number of vessels that should be retained in the manner indicated, but as such steamers are not likely to be constructed in any considerable numbers it is thought that probably ten (10) would be the maximum at all likely to be placed at the disposition of the admiralty within the next five years, at a maximum annual charge of £50,000 ($243,325).

With these objects the admiralty entered into negotiations with the White Star and Cunard Steamship Companies.

The White Star line undertakes to hold at the disposition of the admiralty for purchase or hire at the option of the admiralty, at any time during the continuance of this agreement, the following vessels, without charge, viz:

Names of ships.	Tons.	Value in English money.	Value in United States money.
Britannic	5, 004	£130, 000	$633, 425
Germanic	5, 008	130, 000	633, 425
Adriatic	3, 888	100, 000	486, 650
Celtic	3, 867	100, 000	486, 650

In the event of purchase the foregoing prices are to be held as the values of the vessels on January 1, 1887, plus 10 per cent. for compulsory sale, less an abatement of 6 per cent. per annum on the depreciated annual value for the period that may elapse between the 1st of January, 1887, and the date of purchase by the Government. In such case the company shall be entitled to remove from the ship or ships the plated-ware, cutlery, crystal, earthenware, blankets, counterpanes, and linens, which articles are not to be considered as part of the equipment of the ships. Such quantities, however, as may be necessary for the officers and warrant officers that would form part of the ship's complement if used as an armed cruiser are to be left on board free of charge.

The rate of hire of the before-named vessels, of any or all, is fixed at the rate of 20 shillings per gross registered ton per month if the owner provides the crew, or at the rate of 15 shillings per gross registered ton if the admiralty provide the crew. All risks of capture and of hostilities are assumed by the admiralty. The company is to be allowed seven days' pay at the stipulated rate of hire, for any of the vessels chartered, for taking down cabin fittings not required by the admiralty, and ten days on the same pay at the termination of the service for replacing those fittings, the work of dismounting, dismantling, and reinstating to be performed by the company at the expense of the admiralty.

Should the Government hire and subsequently elect to purchase any steamer under this agreement, three-eighths of the amount of hire paid during the period not exceeding six months immediately preceding the purchase will be allowed by way of rebate from the amount of purchase money provided by these presents.

During the currency of this contract any vessels which may be substituted in the mail service for those before named, except the steamers hereinafter referred to, shall also be subject to the like conditions as regards purchase and hire. In the event of purchase the price shall be fixed at the cost price to the company, with 10 per cent. additional for compulsory sale, less an abatement in the manner previously provided.

The company agree to construct two vessels of such type and speed as shall render them specially suitable for service as armed cruisers, and in accordance with the plans and specifications approved by the admiralty. In consideration the admiralty agree to pay to the company for these vessels so approved an annual subvention, payable half-yearly, at the rate of 15 shillings per gross registered ton per annum, such subvention to commence from the date on which these vessels, respectively, start on their first voyage with the mails, and to be continued yearly for a minimum period of five years, terminable at the end of five years or thereafter on twelve months' previous notice, always provided that no subvention is payable to any vessel after January 1, 1894, if the admiralty shall have given the twelve months' previous notice.

The director of naval construction reports that the plans of these two proposed new vessels provide vessels far in advance of anything that has yet been submitted to the admiralty for the purpose of armed cruisers. They are to be of large size, of exceedingly high speed, provided with twin screws, have their engines and boilers placed below the water-line, be divided into numerous compartments, and have protected steering gear. They will be capable of conveying fully 2,000 men, whom they could land at Bombay via the Suez Canal in fourteen days, or via the Cape in twenty-two and one-half days. Their coal capacity will enable them to keep the sea for probably not less than three months.

In the event of the company ceasing to carry the mails under the contract before the company shall have received five annual subventions, they shall be entitled to receive for any part of the period that may not have expired at the time of the termination of the mail contract a subvention of 20 shillings per registered ton per annum, in lieu of 15 shillings. In consideration of the subvention the company is precluded from entertaining, in connection with any of the vessels referred to in this contract, offers for sale or charter for a period exceeding five weeks, unless in case of a longer charter with the approval of the admiralty previously obtained, without first giving to the admiralty the option of exercising the pre-emption to purchase or hire, such option to be exercised as regards any vessel receiving a subvention within seven days and as regards the other vessels within forty-eight hours.

Should the admiralty elect to charter any vessel receiving the subvention, the rate of hire for such vessel to be at the rate of 20 shillings per gross registered ton per month, the admiralty providing the crew, or 22½ shillings per ton, if the owners are required to find the crew. In the former case the admiralty are to assume all risks, in the latter the risk of loss or damage from hostilities only to be for their account. The terms defined for time allowance, for dismantling and refitting, to apply also to those vessels.

In order that the vessels receiving special subvention may be ready for service as armed cruisers at the shortest possible notice, the company shall afford the admiralty every facility, compatible with the use of the vessels as mercantile ships, for placing on board during the construction of the steamers such permanent fittings and arrangements for their armament on approved plans as will enable them to be prepared for service within a week of arrival and discharge of cargo at Liverpool; and as regards the guns contemplated to be placed upon the upper deck, the admiralty are to provide the racers and other fittings and gun mountings which the company are to keep, if required, in their store-house at Liverpool without charge, ready for immediate placing in the ships at the cost of the admiralty, and to maintain the same in clean order ready for immediate use free of charge.

One-half of the crews employed for these vessels shall consist, as nearly as possible, of men belonging to the Royal Naval Reserve.

Should any of the ships be sold to a British ship-owner approved by the admiralty the privileges of this agreement remain attached to the ships under the new ownership.

The price for the ships receiving the subvention is to be the cost price thereof, subject to the conditions for compulsory sale and abatement previously mentioned, but the admiralty agree not to exercise their pre-emption, as regards purchase only, for two years after their completion.

These two vessels will be completed in about eighteen months (by August, 1888), and the subvention will be an annual charge of £6,500 ($31,632.25) for each vessel so long as they carry the mails, or £8,500 ($41,365.25) should the mails be withdrawn from them.

The existing fleet of the White Star line is placed at the disposition of the admiralty without any charge. The price for purchase is fixed, less an allowance for depreciation, and fixed rates are given for their hire. Although these vessels have not the high speed the admiralty seek to obtain, yet they are undoubtedly fast ocean steamers and will prove efficient transports. The prices named are fair, and afford a protection to the public service against having to pay excessive rates that might be current in time of war.

The Cunard Company agree to hold at the disposition of the Government for purchase or hire during the continuance of the agreement the following vessels, viz:

Name of ships.	Gross tons.	Value in English money.	Value in United States money.
Etruria	7,718	£310,000	$1,508,615 00
Umbria	7,718	301,000	1,464,816 50
Aurania	7,269	240,000	1,167,966 00
Servia	7,392	193,000	939,234 50
Gallia	4,809	102,000	496,383 00

On the following conditions:

A subvention of 15 shillings per gross registered ton per annum to be paid by the Government to the company on account of the Etruria, Umbria, and Aurania during the continuance of the postal contract; but in the event of the termination of that contract before these three vessels have received five years' payment of such annual subvention the company shall be entitled to receive for the balance of such unexpired period a subvention of 20 shillings per gross registered ton per annum, the five vessels being still held at the disposition of the Government in the same manner as if the postal contract was current.

The subvention to be paid half yearly, on the 1st of April and 1st of October, the first payment (for one month) being due on April 1, 1887.

In consideration of this subvention the company engage to hold at the disposition of the admiralty in Liverpool, all or any, of the above-named vessels for hire or purchase, on terms herein set forth immediately, on the completion of the voyage (but after discharge of cargo) on which the vessel may be engaged at the time of the receipt of the notice of the admiralty's intention to purchase or hire. The vessels under agreement may be annually inspected by the admiralty.

The company are precluded from entertaining, in connection with any of the five vessels named, offers for sale or charter for a period exceeding five weeks (unless in case of a longer charter, with the approval of the admiralty previously obtained), without giving the admiralty the option of exercising the pre-emption to purchase or hire—such option to be exercised as regards the Etruria, Umbria, and Aurania, all or any, within seven days; and as regards the Servia and Gallia, either or both, within forty-eight hours.

In the event of purchase, the foregoing prices are to be held as the values of the vessels on January 1, 1887, plus 10 per cent. for compulsory sale, less an abatement of 6 per cent. per annum on the depreciated annual value for the period that may elapse between the 1st of January, 1887, and the date of purchase. The company is allowed to remove articles not considered as part of the equipment, as stipulated in the contract with the White Star Company.

In the event of charter by the admiralty the rate of hire for the Etruria, Umbria, and Aurania, all or any, is to be 20 shillings per gross registered ton per month, without crew; and the rate of hire for the Servia and Gallia, either or both, is to be 15 shillings per gross registered ton per month, without crew. The time allowance for dismantling and reinstating cabin fittings is the same and under the same conditions prescribed in the contract with the White Star Company.

In order to have the Umbria, Etruria, and Aurania ready for service as armed cruisers at the shortest possible notice, the company shall afford the admiralty every facility compatible with their present use as mercantile ships for placing on board such fittings and arrangement for their armament as will enable them to be prepared within a week of their arrival at Liverpool and discharge of cargo. For this purpose the company consent to the admiralty fitting the permanent supports and platforms for the four guns to be carried on the poop and forecastle.

As regards these four guns and the eight guns contemplated to be placed on the upper deck, the admiralty are to provide the racers and other fastenings and gun mountings, which the company are to keep stored, if required, without charge, ready for immediate placing in the ships at the cost of the admiralty, and to maintain the same in clean order ready for immediate use free of charge.

One-half of the men employed as the crews of these vessels are to be Royal Naval Reserve men.

Conditions of transfer to a British owner approved by admiralty are the same as in contract with the White Star Company.

If the company determine to build new ships for the mail service they will submit the plans to the admiralty that they may be constructed to be suitable for armed cruisers; and if the plans be approved such vessels are to be taken on similar terms to these specified for the Umbria, Eturia, and Aurania.

This contract commenced on March 1, 1887, and is to continue for a period of five years, terminable then or thereafter by twelve months' previous notice.

The annual expenditure for the retention of these vessels will amount to an average of £5,400 ($26,279.10) each.

The British admiralty have been in communication with other large ship-owners, but so far the matter has not taken definite shape except as regards the White Star and Cunard Companies.

The question of a Canadian route to the East was brought up in the British Parliament April 30, 1887. This route is by way of the Canadian Pacific Railroad and a line of subsidized steamers in the Pacific to ply between the terminus of the railroad and British possessions in India and the East, and Australia. The Canadian Pacific Railroad Company have offered to build five first-class steamers, on plans approved by the admiralty, to maintain a speed of 18 knots, and to be immediately available for conversion into armed cruisers. The Government is to pay £100,000 ($486,650) per annum for a tri-weekly service, or £60,000 ($291,990) per annum for a monthly service. It is expected that Canadian subscriptions will reduce the amount required of the Government by £15,000 ($73,977.50). These vessels will serve as transports, and in consideration of the subsidy they will carry mails free. All war material, troops, and stores are to be transported by the Canadian Pacific Railroad and these steamers at actual cost.

Foreign countries as a rule subsidize steamship companies for carrying the mails on such terms as will induce the building of ships. The following table from the Report of the Superintendent of Foreign Mails shows the amount of subsidies paid for carrying foreign mails:

Countries.	Amount of subsidy per annum.	Countries.	Amount of subsidy per annum.
1. France	$5,152,388 88	7. Netherlands	$101,975 60
2. Great Britain	3,206,766 67	8. Austria	43,106 55
3. Brazil	2,223,958 10	9. Denmark	32,469 54
4. British India	350,724 12	10. Portugal	23,964 61
5. Japan	241,250 00	11. Argentine Republic	6,229 07
6. Belgium	134,793 32	12. Roumania	984 87

The conditions of the contracts vary, but while all stipulate for carrying the mails yet in some it is distinctly stated on what terms the Government may have the right to use the vessels in case of war.

In the contract of the French Government with the Messageries Maritimes Steamship Company it is stipulated that, in case of war, the Government will have the right to take possession of the steamers and will pay 5 per cent. interest on the capital and reimburse the company the appraised losses or damages.

The French law of January 29, 1881, offers a navigation bounty to French ships, and increases that bounty by 15 per cent. for ships built in France in accordance with plans and specifications approved by the ministry of marine. These steamers must have such water-tight subdivisions, that if any one compartment be flooded, the others will keep the ship afloat; the boilers and engines must satisfy prescribed tests; the speed is to be at least 13½ knots; coal endurance sufficient to steam 6,000 miles, at 10 knots; storage of coal to protect boilers and engines, especially all such parts of the engines which are above the water-line, and the propeller must be under water. These ships must be arranged to carry a number of 14-centimetre (5.5-inch) guns, to be designated by the minister of marine in accordance with the plans of the ship. Gun ports, platforms, and other permanent fittings are to be placed in the ship during construction. The guns, carriages, pivot-bolts, and fittings will be furnished by the ministry and will be stored in a Government storehouse on shore.

Special suitable arrangements must be provided to receive and store the necessary ammunition on board with safety when required.

The law of 1881 gives bounties for all ships built in France, but only those which are engaged to carry the mails are required to have special fittings to make them useful as cruisers in war. Later postal contracts require the mail steamers to have these fittings, and a premium for speed is also granted to vessels in the postal service.

The French ministry also provide for the employment of the of *personnel* the mercantile service in the navy, and it is contemplated to provide suitable training for this *personnel*. This is not yet definitely settled.

Italy supports Italian steamship companies by an annual subsidy of $1,570,938.17. The carriage of the mails is obligatory. Civil and military employés are to be given transportation at half price.

An Italian law of 1886 gives a special premium of $5.79 per ton for every iron or steel ship built in Italy, and $1.93 for every horse power of engines and boilers built in Italy and fitted in an Italian ship. These premiums will be increased by from 10 to 20 per cent. for such vessels which may be suitable for use as cruisers in time of war. This special premium will also be given to other vessels purchased by Italian ship-owners if suitable for use as cruisers.

These special premiums and other concessions to the merchant marine of Italy cost the state about $812,000 per annum.

The Spanish Government has approved a contract with the Spanish Transatlantic Steamship Company. The Government is to pay $1.83 per mile run on an American line, and lesser amounts for services to the Philippines, Buenos Ayres, and Fernando Po; payments to be made monthly by the minister of foreign relations. The steamers on the American line are to be of 4,500 tons. The company's vessels are to carry the mails and perform whatever extra services may be required for war purposes. All the vessels are to be of iron or steel and strong enough to carry heavy batteries.

In Russia the Volunteer or Patriotic Merchant Fleet has been definitely established in order that the merchant service may be auxiliary to the navy in time of war. New regulations were made in 1885 by which this company received special subvention and were given the mail contract for six years between Odessa and ports of the North Pacific Ocean. This company is directed by a special committee in official communication with the ministry of marine, and has its principal office in St. Petersburg.

In 1885 these vessels were armed as cruisers as follows:

In the Baltic: The Rossja-Moskiver and Petersburg, each armed with one 8-inch rifled mortar, six 6-inch Abouchoff breech-loaders, and two Hotchkiss. In the Black Sea: Vladimir, two 6-inch Abouchoff, three 4-pounders, and two Hotchkiss; Rossja II, six 8-inch Abouchoff, three 6-inch Abouchoff, one 6-inch rifled mortar, four 9-pounders, and 6 Hotchkiss; Constantine,. one 6-inch Abouchoff, six 4-pounders, and two Hotchkiss; Vesta, five 6-inch rifled mortars, three 9-pounders, and four Hotchkiss.

The three following vessels of the fleet were not armed, viz: Czar, Czarevna, Czarawitch. Each of these was to have armaments in case of war consisting of one 8-inch Abouchoff, six 6-inch Abouchoff, four 9-pounders, and six Hotchkiss.

The Russian Government pays this company an annual subsidy of 599,250 rubles, = $389,306.50, on condition that the vessels perform voyages amounting to 141,000 miles annually.

Germany has subsidized four lines of steamers for a period of ten years, and pays $64,172.50 for a portion of the service, and paid for the other portion, a sum according to the postal service rendered.

Germany specially provides for the utilization of the *personnel* in the naval reserve and see-wehr. Officers and men are enrolled and specially trained for transfer to the navy from the merchant marine in case of war.

W. H. BEEHLER,
Lieut., U. S. Navy.

MACHINERY.

TRIPLE-EXPANSION ENGINES.

The triple-expansion is fast superseding the compound engine in the naval as well as in the merchant service, and it is now an unusual thing for a vessel in either service to be designed with compound engines. The fact of its almost universal adoption for merchant-steamers should in itself be sufficient evidence of its economic working. Trustworthy data of the actual coal consumption for sea voyages are difficult to obtain, owing to the method of measuring coal in merchant steamers. From indicator diagrams taken from the engines of one of the transatlantic steamers, corrected for average speed, revolutions, and power, the consumption was found to be 1.65 pounds, which is probably about the average for well-designed engines. In the naval service no extended trials have thus far been made with triple-expansion engines. The consumption for the twelve hours' natural-draft trial of the Spanish torpedo-vessel Destructor at low speed was 1.95 pounds; that for the six hours' trial of the English torpedo-vessel Rattlesnake, 2 pounds, and for the four hours' trial of the gunboat Lizard, 1.89. At forced draft the consumption of the Destructor for three hours was 2.4, and that of the Lizard for four hours, 2.12 pounds.

The tables at the end of this article have been prepared with a view to giving the general data of triple-expansion engines as adopted in the naval and merchant service, and to show how largely high piston speed enters into the design of modern engines of high power and light weight. The table of compound engines is added for the purpose of comparison and for general information. The difficulty in obtaining reliable data of the horse-power of merchant steamers is great, and the estimates usually far in excess of the actual performances; but in comparing them with naval engines it must be borne in mind that, unless otherwise stated, the power of the merchant steamer is that for natural draft.

In connection with this subject, it is thought well to give the conditions which should obtain in modern engines to insure successful working, many of the statements being taken from a paper on High Speed Engines, by Messrs. Marshall and Weighton, of the firm of Hawthorn, Leslie & Co., Newcastle, England, and embodying the results of the experience of that firm.

The successful introduction of the triple-expansion engine has shown that from the more equable balance attainable in the division of power by its application to three cranks, considerably increased speed of revolution may be adopted without risk of excessive wear and tear. Where weight is such an important factor as it is in naval engines, this increased speed is most economically got with short strokes and increased number of revolutions, and all modern engines are designed for a much higher piston speed than was the practice a few years ago. As will be seen by reference to the table, the highest speed yet reached is 1,023 feet, being that of the Destructor. On one of her preliminary trials, using a screw of finer pitch, this speed was as high as 1,100 feet per minute.

There seems to be a tendency in the merchant service to do away with steam jackets, especially for the H. P. cylinder, and a number of engines have been built without jackets for any of the cylinders. This seems to be due more to a question of expense in building than to any doubt of the actual necessity for them; for aside from the facility of renewing a liner, there appears to be little doubt of the economy resulting from their use when proper attention is given to draining them, and the best practice seems to be to retain them, especially for naval engines. The Destructor's cylinders are not jacketed, but in her case reduction of weight was of such paramount importance that much had to be sacrificed to it.

The tables give a good idea of the prevailing practice regarding diameter of cylinders. All of the belted cruisers have engines designed to develop 5,500 I. H. P. with natural, and 8,500 with forced, draft. Thus far the Orlando is the only one that has had a trial, having developed 5,617 with natural, and 8,622 with forced draft. On the natural-draft trial the power was quite equally distributed between the cylinders; but with forced draft more than 45 per cent. of the total power was developed in the L. P. cylinders, as shown below:

Cylinders.	Indicated horse-power.					
	Natural draft.			Forced draft.		
	H. P.	I. P.	L. P.	H. P.	I. P.	L. P.
Starboard engine	853	956	996	874	1, 442	1, 997
Port engine	856	973	983	990	1, 389	1, 930
Total	5, 617			8, 622		

The distribution of power on the forced-draft trial of the Destructor was 1,020 in the high pressure, 1,360 in the intermediate, and 1,404 in the low-pressure cylinders.

As to main steam valves, the H. P. is almost invariably of the piston type. For the others, there is a variety of practice: in some cases the I. P. and L. P. are slides, in others only the L. P., while piston valves are frequently adopted for all three. This is the case with the Destructor, there being two for each I. P. and L. P. cylinder and one for the H. P. The resistances of valves when working at high speeds are very great, especially with large valves; high speed entails large steam passages, and therefore increased weight of valves; and when it is considered that the resistance varies as the product of some function of the weight of the valve and the square of its speed, the necessity of some provision for counteracting this resistance will be apparent. From a series of experiments made by Hawthorn, Leslie & Co., with light and heavy valves, it was found that the maximum strains were greatly in excess of the mean, and that they occurred at the beginning of the stroke of the valve. The nature of the diagrams obtained and the facts of the case pointed to inertia and momentum as the chief causes concerned. The valves were of the piston type, and the valve-gear Marshall's. The following formulas express the relation between the maximum and mean resistances as deduced from these experiments:

$$S = \frac{R^2\sqrt{W}}{50} \qquad S_1 = \frac{R\sqrt{W}}{2.84}$$

in which S and S_1 are respectively the maximum and mean resistances in pounds, R the number of revolutions, and W the weight of the valve and stem.

The steam passages and ports should be as large as the circumstances of piston speed and weight will allow; and where reduction of weight is all important a compromise is usually made between increase of piston speed and enlargement of valves and passages. In the vertical compound engines of the Panther, given in one of the tables, the velocity of steam in feet per second through the ports was 150 in the H. P., and 266 in the L. P., that of exhaust being 100 and 123. For the triple-expansion engines of the Iljin, the estimated velocity of steam is 130 in H. P., 200 in I. P., and 320 in L. P., that of exhaust being 110, 140 and 153.

The valve-gear in most general use is some variety of the radial type.

One feature which demands special attention in the design of high-speed engines is the balance of the moving parts. The weight of the cranks and part of the connecting rods should be accurately balanced by means of balance weights, while the momentum of the purely reciprocating parts, consisting of piston and rod and part of connecting rod, should be counterbalanced by a proper adjustment of the compression of steam at the end of the stroke. It may be laid down as a sound general principle that, for high speed, the motion of all reciprocating parts of any considerable weight and speed ought to be cushioned, but the practical solution of the problem in the case of heavy valves has been one of great difficulty. With a view to equalizing the driving effort on the crank-pin, a good deal may be done by a judicious proportion of weight in the reciprocating parts relatively to their speed, and to the variation of pressure on the piston due to the expansion of the steam.

When considerations of economy and reduction of weight are not carried too far, the crank-shaft is made in three interchangeable sections, the eccentric sheaves being frequently fastened on the couplings. The sequence of cranks is a question about which there has been some discussion, but the prevailing practice seems to be high, low, and intermediate. The bearing surfaces are made as large as the limits of space and weight will allow. In the case of the horizontal engines of the Naniwa-Kan, the actual pressures were 725 pounds per square inch on the crank-pins, 310 on the main bearings, and 84 on the guides. For the vertical engines of the Panther the corresponding figures were 650, 260, and 80.

The air, circulating, feed, and bilge pumps are each run by its own engine. Although this involves increase of weight it is more than offset by the fact that each can be more accurately adapted to the work it has to do than if it were worked from the main engine.

When it comes to type of engine, there is little difference, as regards weight-efficiency, between the horizontal and the vertical. The vertical, being susceptible of a better balance and running with less friction, may be driven at a higher piston speed than the horizontal without exceeding the limits of safety and durability; and, therefore, in ships of sufficient draught questions of durability and economy usually decide in favor of the vertical, which must, however, be carefully and thoroughly stayed. The engines of the Panther gave trouble at first on account of strains set up in the engine itself, due to a too rigid attachment to the hull of the vessel. A stay was fixed transversely to the bulkhead and to the top of the cylinder. After it was removed no difficulty was experienced.

As illustrating how weight is economized in the modern engine, the cylinder supports of the engines of the Russian iron-clad Sinope are utilized as cross-head guides.

The type of boiler is a most important factor in the development of high power with small weight. Between the return tube and the straight through type fitted in most of the smaller English ships of recent design, there is little difference as regards weight-efficiency; but the boiler which gives the greatest ratio of heating surface to weight is the modified locomotive, and is the one adopted in such vessels as the Folgore, Tripoli, Montebello, Iljin, Rattlesnake, and Destructor. In these boilers the fire-box, instead of terminating at the level of the grate-bars, is carried down and formed into what is practically a water bottom, from which a steady supply of water is afforded to the whole length of surface forming the sides of the fire-box. A combustion chamber is introduced behind the grate-bars, which not only assists combustion but prevents the intense heat from playing directly on the tube sheet. Salt water is not fed into these boilers, the deficiency of feed being made up from a fresh water supply. On her twelve hours' endurance trial, at 11.6 knots, the Destructor, developing 297 I. H. P., used three-fourths of a pound per I. H. P. per hour to make up this deficiency.

Forced draft is, of course, a *sine qua non* to the development of high power with relatively small weight. It has been demonstrated that the power can be thus increased about 50 per cent. with a saving in weight of about 25 per cent.

The screw adopted for the effective transmission of the power forms in itself a subject of the closest study. The trials of the Destructor furnish very instructive data, and show what changes had to be made before satisfactory results were obtained. The indicated horse-power required was 3,800 and the speed 22.5 knots, on a displacement of 385 tons. The vibration set up with some of the screws was excessive, and it was only after repeated experiments that one was found which would work off all the power of the engines, and which would not at the same time produce too much vibration in the hull of the vessel. The particulars of the different screws, and the results obtained, are given in the following table:

	1	2	3	4	5	6	7
Diameter ....feet..	7½	7½	7¼	7¼	7¼	7¼	7¼
Pitch ....do...	8½	9½	9½	9	9	9½	9⅛
Area ....square feet..	14	14	12¼	12¼	14	14	11¼
Revolutions	315	278	305	305	....	....	293–292. 3
I. H. P	3, 400	3, 400	....	3, 400	....	3, 800	3, 784–3, 829
Speed of vessel....................	21	21. 6	....	....	21. 75	22	22. 56–22. 68

All of the above screws were three-bladed. Nos. 1, 2, 3, and 4 were made of manganese bronze, and Nos. 5, 6, and 7 of forged steel, galvanized. The screws of the Rattlesnake are of manganese bronze, three-bladed, 6 feet 6 inches in diameter and 7 feet 6 inches pitch. On her last trial they were run at 322 revolutions, and drove the vessel 19½ knots with 2,860 horse-power.

As regards material, mild steel is always used for the boilers. In the engines, forged steel is used for piston rods, connecting rods, valve gear, stays, bolts, and shafting; and by making them hollow and of slightly increased dimensions, a considerable saving in weight is effected, the strength being unimpaired and the stiffness increased. Forged steel has been used for pistons up to 45 inches diameter, and has been found to be superior to cast, and in the long run less costly, being more elastic, more uniform, and more reliable. Great difficulty is experienced in getting steel castings sufficiently thin to effect any material saving in weight for small parts. For pistons, piston valves, cross-heads, and slides, however, there is little difficulty, and where sound castings are obtained a saving of about 25 per cent. in weight is effected. For propeller blades it is almost impossible to obtain thoroughly sound castings, owing to the inequality in thickness and the fine edges which are necessary for the blades in the case of high-speed engines.

The condenser is usually cylindrical, and made of sheet brass, the end plates being brass castings.

For bearing surfaces, white metal gives the best results, and is in very general use, being inserted in the bearings in the form of strips.

Where so much attention is paid to weight, every component part is thoroughly tested before being used, and in this way the apparent factor of safety may in many cases be reduced.

TRIPLE-EXPANSION ENGINES. I.

Name of vessel.	Diameter of cylinders.			Stroke.	Piston speed.	I. H. P.	Boiler pressure.	Grate surface.	Heating surface.	Condensing surface.	Weight of machinery including water.
	H.P.	I. P.	L. P.								
Nile	43	62	96	51	*a*807	*a*12, 000	135	604	19, 390	15, 000	1, 050
Trafalgar	43	62	96	51	*a*807	*a*12, 000	135	604	19, 390	15, 000	1, 050
Victoria	38	58	88	48	....	*a*12, 000	130	......	....	......	1, 400
Sanspareil	38	58	88	48	....	*a*12, 000	130	......	....	....	1, 400
Australia	36	51	78	42	....	*a*8, 500	130	540	....	....	800
Galatea	36	51	78	42	....	*a*8, 500	130	540	....	....	800
Aurora	36	51	78	42	....	*a*8, 500	130	540	....	....	800
Immortalité	36	51	78	42	....	*a*8, 500	130	540	....	....	800
Orlando	36	52	78	42	832	8, 662	130	540	....	....	800
Undaunted	36	52	78	42	....	*a*8, 500	130	540	....	....	800
Narcissus	35	51	78	42	....	*a*8, 500	130	540	....	....	800
Serpent	26	37	57	33	....	*a*4, 500	140	250	....	....	380
Racoon	26	37	57	33	....	*a*4, 500	140	250	....	....	380
Bramble	18½	29	43	24	732	1, 042	140	......	....	....	....
Lizard	18½	29	43	24	732	1, 025	140	......	....	....	....
Rattler	18½	29	43	24	810	1, 291	140	......	....	....	....
Wasp	18½	29	43	24	772	1, 157	140	......	....	....	....
Rattlesnake	18½	27	42	18	966	2, 860	140	122	5, 000	4, 000	....
Reina Regente	40	60	92	45	*a*862	*a*12, 000	140	658	*c*22, 500	15, 000	1, 170
Destructor	18½	27	42	21	1, 023	3, 829	145	144	5, 920	5, 000	153
Sinope	44	63	95	45	....	*a*12, 000	125	......	....	....	900
Baltimore	42	60	94	42	770	*a*10, 750	135	624	16, 900	12, 500	900
Gunboat No. 1	22	31	50	30	....	*a*3, 000	160	220	....	4, 900	320
Montebello	15½	24	37	16	*a*1, 066	*a*4, 200	160	148	6, 740	....	136
Dogali	30	45	73	33	842	7, 600	150	......	....	....	....
Iljin	17½	27	42	18	*b*1, 050	3, 550	160	182	7, 746	....	155

a Estimated. *b* Estimate for 4,000 I. H. P. *c* Approximate.

All of the above are twin-screw engines except the Bramble, Lizard, Rattler, and Wasp, which are single-screw, and the Montebello, which is triple-screw.

TRIPLE-EXPANSION ENGINES. II.

Name of vessel.	Diameter of cylinders.			Stroke.	Piston speed.	Boiler pressure.	I. H. P.	Grate surface.	Heating surface.	Condensing surface.
	H. P.	I. P.	L. P.							
Ormuz	46	73	112	72	840	150	8,000	......	....	....
Aller	44	70	108	72	828	150	6,890	800	22,630	12,020
Saale	44	70	108	72	(*a*)	150	(*a*)	(*b*)	22,630	12,020
Trave	44	70	108	72	(*a*)	150	(*a*)	(*b*)	22,630	12,020
Oroya	40	66	100	72	774	160	6,750	627	17,640	11,546
Orizaba	40	66	100	72	756	160	6,500	627	17,640	11,546
Oaxaca	40	64	92	60	700	145	3,417	......	....	....
Champagne	49.2	2–49.2	3–74.8	66.9	658	114	7,054	896	24,854	15,016
Bretagne	49.2	2–49.2	3–74.8	66.9	(*c*)	114	(*c*)	896	24,854	15,016
Trans-Pacific	34	56	90	60	....	150	*d*4,000	334	11,378	6,045
Bengal	35	56	89	66	....	140	*d*3,200	328	....	7,000
Coromandel	35	56	89	66	....	140	*d*3,200	328	....	7,000
Carmarthenshire	27	43	70	45	568	150	2,340	......	6,000	....
Buffalo	33	54	86	60	570	160	2,278	326	9,751	....
Libra	25	42	67	42	616	150	1,966	160	5,300	....
Sobralense	2–17	38	60	42	532	150	1,580	168	4,400	2,750
Wells City	21½	36	57	36	438	142	1,046	108	2,700	....
Bléville	21	33	52	42	490	160	1,223	*e*72	....	....
Westmoreland	20	33	54	36	420	150	900	68	2,400	1,450
Draco	21	32	56	36	....	110	600	......	2,270	....
Royal Prince	20	33	54	39	481	150	767	72	2,700	1,300
Vespasian	17	29	46	30	*d*400	160	*d*600	70	2,200	1,300

a About the same as for Aller.
b Grates have been shortened—about 700 square feet.
c About the same as for Champagne.
d Estimate.
e Has fan for forcing the draft.

COMPOUND ENGINES. III.

	Diameter of cylinders.		Stroke.	Piston speed.	I. H. P.	Boiler pressure.	Grate surface.	Heating surface.	Condensing surface.	Weight of machinery, including water.
	H. P.	L. P.								
Anson	52	2–74	45	816	12, 567	90	756	20, 244	17, 000	1, 150
Benbow	52	2–74	45	763	10, 853	90	756	20, 244	17, 000	*a*1, 200
Camperdown	52	2–74	45	764	11, 741	90	756	20, 244	17, 000	*a*1, 200
Howe	52	2–74	45	804	11, 725	90	756	20, 294	17, 000	1, 152
Rodney	52	2–74	45	776	11, 158	90	756	20, 294	17, 000	1, 152
Collingwood	52	2–74	42	669	9, 573	90	756	20, 294	17, 000	1, 244
Impérieuse	55	2–77	48	704	9, 978	90	676	22, 800	16, 000	1, 316
Warspite	55	2–77	48	698	10, 242	90	676	22, 800	16, 000	1, 316
Hero	42	84	36	659	6, 159	90	507	14, 224	9, 500	....
Mersey	38	64	39	795	6, 628	110	399	11, 700	10, 000	*a*600
Severn	38	64	39	798	6, 335	110	399	11, 700	10, 000	*a*600
Thames	37	63	39	771	5, 871	110	380	11, 652	10, 000	560
Forth	37	63	39	*b*767	*b*5, 700	110	380	11, 652	10, 000	560
Amphion	46	86	39	617	*c*5, 661	90	546	15, 160	10, 000	750
Arethusa	42	78	48	728	*c*4, 666	90	536	14, 562	11, 000	750
Leander	42	78	48	770	*c*4, 658	90	536	14, 562	11, 000	750
Phaeton	42	78	48	802	*c*5, 588	90	536	14, 562	11, 000	750
Archer	27	50	33	862	3, 982	120	224	5, 900	5, 640	350
Brisk	27	50	33	....	3, 954	120	224	5, 900	5, 640	350
Cossack	27	50	33	858	3, 815	120	224	5, 900	5, 640	350
Mohawk	27	50	33	....	3, 735	120	224	5, 900	5, 640	350
Porpoise	27	50	33	847	3, 943	120	224	5, 900	5, 640	350
Tartar	27	50	33	863	3, 824	120	224	5, 900	5, 640	350
Scout	26	46	30	762	3, 370	120	204	6, 170	5, 200	320
Fearless	26	46	30	....	....	120	204	6, 170	5, 200	320
Alacrity	26	50	34	764	3, 173	100	218½	7, 032	4, 200	360
Surprise	26	50	34	754	3, 017	100	218½	7, 032	4, 200	360
Blitz	35. 4	59. 8	26	635	2, 808	85	297	8, 482	5, 400	388
Giovanni Bausan	43	82	36	696	6, 680	90	450	15, 256	9, 000	680
Etna	44	85	36	....	....	100	560	17, 222	11, 517	....
Folgore	19½	35	16	*b*1, 066	*b*2, 800	130	105	4, 464	....	93
Tripoli	19½	35	16	1, 013	3, 800	130	......	....	....	....
Panther	34	68	36	849	6, 645	135	430	12, 620	....	540
Leopard	34	68	36	....	....	135	430	12, 620	....	540
Naniwa	44	85	36	730	7, 650	100	392	15, 114	13, 500	710
Takachiho	44	85	36	....	....	100	392	15, 114	13, 500	710

a Approximate. *b* Estimated. *c* Jet in smoke pipe.

The cylinders given are those for each engine, while the condensing surface is that for both. All of the engines are twin-screw, except the Tripoli, which is triple.

BANKED FIRES.

The following extract, with table, taken from Die Schiffsmaschine, Vol. 1, pp. 176 and 177, has already been published in the Proceedings of the Naval Institute, Vol. XII, No. 4, 1886. Its interest to the naval service, however, is sufficiently great to be reproduced in this publication :

"It is a widespread error to suppose that banking fires, especially in large boilers with large water spaces, even for two or three days at a time, is more economical than hauling fires and starting them again.

"By referring to the accompanying table, in which are given data collected from the ships named, it will be seen that the amount of coal required to keep banked fires in large boilers for about 20 hours, and in small ones for about 30 hours, is equal to the amount required to start the fires.

"The quantity of fuel required to heat the water is not considered, because it is about the same in either case. It will be seen from the table that with banked fires the weight of coal per furnace per hour is, for small boilers, 16 to 18 pounds; medium, 22 to 24 pounds; large, 26 to 31 pounds; and for starting fires it requires on an average, in round numbers, from 21 to 25 pounds per square foot of grate. Taking into consideration that banking fires is only economical when the period for which the engines are to be stopped does not exceed about 24 hours, and that even in this case the life of the boiler is much shortened, we must conclude that fires should never be banked for more than a few hours except when anchored in an unsafe harbor, or in cases where the exigencies of the service may require the use of the engines at very short notice."

Name of vessel.	I. H. P. of the engines.	Average weight of coal required in pounds.				Number of hours in which the amount used under banked fires becomes equal to amount required for starting fires.
		For starting fires.		Under banked fires.		
		In all furnaces.	Per square foot of grate.	For all fires for 24 hours.	For one fire per hour.	
König Wilhelm	8,000	22,047	24	26,456	28	20.0
Kaiser and Deutschland	8,000	26,456	30	30,865	32	20.5
Kronprinz	4,800	17,640	24	19,845	26	21.3
Friedrich Karl	3,500	13,230	23	22,047	35	14.4
Preussen	5,400	13,230	19	19,845	28	16.0
Friedrich der Grosse	5,400	16,537	24	22,047	31	18.0
Sachsen and Class	5,600	22,047	30	21,168	28	25.0
Leipzig and Class	4,800	17,640	28	15,432	23	27.4
Bismarck and Class	2,500	8,820	23	10,584	22	20.0
Hertha and Vineta	1,500	7,938	28	8,820	23	21.6
Mars	2,000	12,127	28	10,584	22	27.5
Ariadne and Louise	2,100	7,717	29	7,716	23	24.0
Nymphe	800	3,969	30	3,306	17	28.8
Zieten	2,350	6,615	28	4,409	15	36.0
Loreley	350	1,654	24	2,117	22	18.7
Habicht and Möwe	600	2,646	25	1,764	18	36.0
Albatross and Nautilus	600	2,646	23	2,205	15	28.8
Wolf and Class	340	1,654	28	1,587	17	25.0

REMARKS.—The fires are kept in condition to raise steam at half an hour's notice.

R. S. GRIFFIN,
Assistant Engineer, U. S. N.

ORDNANCE.

GUN STEEL.

Probably the most valuable paper that has of late appeared upon the treatment of modern gun steel is that contributed by Col. E. Maitland and read (March 15 last) before the Institution of Civil Engineers in England. So important is this subject, and so eminent the authority, that we take the liberty of quoting from the paper at considerable length. "The gun steel used in England, and practically by the other two great gun-making nations, France and Germany, is a ductile material, a test-specimen of which breaks under tensile strain at about 30 tons per square inch in the soft or annealed state, and at about 45 tons per square inch when hardened by being plunged, at a temperature of 1,450° Fahrenheit, into a bath of cool oil. Chemically it contains from 0.25 to 0.5 per cent. of carbon, and from 0.05 to 0.08 per cent of manganese." The specifications for the test of gun steel used in England at the present time were issued in November, 1886, the text of which is as follows:

"In France and Germany the actual specifications and tests differ somewhat from the British ones, and from each other, but the quality of steel aimed at is substantially the same, except that the French steel is higher in carbon and tensile strength."

In speaking of the character and manner of working steel ingots, Colonel Maitland says: "Let it be supposed that a quantity of steel of uniform quality is run into the mold, either from crucibles or from the open-hearth furnace. As it cools its uniformity disappears; the lower three-quarters or two-thirds becomes solid, while the upper quarter or third presents the deep spongy V, which contains most of the impurities and the gases which have been unable to escape. This upper portion of the ingot is chiefly waste, and represents considerable loss to the manufacturer, though it is understood that the process of subjecting the fluid ingot to pressure, as practiced by Sir Joseph Whitworth & Co., considerably reduces the amount of waste. The distribution of carbon and manganese is considerably affected by the conditions of cooling, whether retarded by a brick lining to the mold or by other means. Generally it may be taken that the parts first solidified represent most nearly the average of the ingot, the carbon and the manganese being caught and imprisoned. In the parts which remain longest fluid the carbon and the manganese rise, so that the middle of the lower part of the ingot is the softest and the middle of the upper part the hardest.

* * * * * * *

"It will probably be agreed that the greatest uniformity of quality will be obtained by cutting off, say, one-third from the top of the ingot, and boring through the centre a hole having a diameter equal to about a quarter the mean diameter of the ingot.

By the French Government this is so fully recognized that 28 per cent. of the upper part and 4 per cent. of the lower part of the ingot have to be cut off before forging. The central metal of unequal quality is also removed. If the forging is for a long tube, it is drawn out under the hammer and bored afterwards; if it is for a hoop, it is bored first and then mandrelled out to the required circumference.

"This also is approximately the practice of the Royal Gun Factory for small forgings, except that it is not considered necessary to cut off 4 per cent. from the bottom of the ingot."

In relation to the erosions of the bore and the life of modern steel guns, the paper continues as follows: "The 68-ton gun of the English service design, of which the first has been recently successfully tested, furnishes good examples of the qualities required for various portions of the construction.

"The rear half of the bore is lined with a thin steel tube, which covers the powder chamber, the seat of the projectile, and all that part of the bore which is most affected by the rush of the products of explosion. In the larger guns the wear of the bore is of very serious consequence, and it practically forms the limit of the serviceableness of the weapon. For instance, an 11-inch B. L. gun used for proof of powder was found to have a tube of very unsuitable quality for resisting the action of the gas, and it became so worn as to be quite unserviceable after firing 95 rounds. It was then furnished with a thin liner of much better gas-resisting quality of steel, and has now fired 239 rounds (18th of February, 1887). It is considerably worn, but is not yet unserviceable. Thus the endurance of a gun before having to be returned to the factory for repair will be at least twice as great with a good liner as with a bad one.

"This subject has been engaging the attention of the officers of the Royal Gun Factory for the last two years, and a great number of experiments have been made to ascertain the qualities of steel best suited to resist erosion of the bore.

"The details will be found in a joint paper written and laid before the Iron and Steel Institute in October, 1886, by Sir Frederick Abel, Hon. M. Inst. C. E., and the author. The general result was that thorough forging was required to insure the best resistance to erosion, and that it was necessary to put three units of forging-work into the metal, taking the unit of work as that done in doubling or halving the length of the forging. A fibrous condition was thus induced; further, it appears probable that gun-steel breaking at about 40 tons per square inch in the specimen, oil-hardened at 1,450°, is best suited for bringing to this fibrous condition, although it matters little whether the steel be high, medium, or low compared with the great differences due to much or little forging."

As to the effect of hammering steel, men of experience are widely at variance, some even going so far as to state that steel should never be touched with a hammer, as the blows instead of making a compact metal fill the forging with innumerable fissures which weaken it, while, on the other hand, the experiments made at the Royal Gun Factory of England for the purpose of ascertaining what effect hammering actually has upon metal of this kind has resulted in a complete victory for the forged steel.

In the test of hoops for new guns, the practice in the United States, as well as in England, is to cut some specimens from across the faces of the forgings to ascertain the circumferential strength. These pieces are cut straight, and consequently their tests do not represent the exact conditions of strain to which a hoop will be subject. Experiments leading to a better system are now in progress in England. They consist in driving a mandrel through a section of the hoop or a circular test-piece of the same metal. The mandrel and also the hole through the specimen has a taper of 3°, and suitable metal for guns (after being oil-tempered and annealed) should sustain an extension equal to one-eighth of the diameter of the hole without showing any signs of failing, even when the piece is thus expanded with one blow of the hammer. A test of this kind has been included in the French contracts for some years, and seems to be much closer to the test of actual practice than that of breaking small pieces in a testing machine.

UNITED STATES TESTS OF GUN METAL.

The specifications for gun steel, which were lately issued, to govern contracts for the metal furnished the Navy for the new high-powered B. L. R., are mainly contained in the following extracts:

It is intended to distribute the gun steel to the different calibres as follows:

6-inch guns	46.
8-inch guns	4.
10-inch guns	24.
12-inch guns	2.

The Department reserves the right to alter the number of guns of each calibre shown above, or to introduce new calibres above 8 inches, but not above 12 inches.

The total weight of steel ordered is not, however, to be less than about 1,221 tons.

All raw material shall be chemically analyzed in the most approved manner, by the contractor, before use, and proper records thereof, and proper melting records, shall be kept by him.

Forgings are to be made of open-hearth steel, of domestic manufacture, from the best quality of raw material, uniform in quality throughout the mass of each forging and throughout the whole order for forgings of the same calibre, and free from slag, seams, cracks, cavities, flaws, blow-holes, unsoundness, foreign substances, and all other defects affecting their resistance and value.

The trunnion band is to be an unhammered steel casting, rough bored and turned, annealed, oil-tempered, and again annealed. The rules herein given for forgings apply also to trunnion bands, except in cases where such rules are evidently unsuited to the production of a sound and perfect unhammered casting, showing the physical qualities laid down in the table.

Ingots shall be cast solid, and are to have an excess of weight of 40 per cent. above that of the rough unbored forging with specimen ends on. Of this excess at least 30 per cent. of the weight of the ingot will be discarded from the upper end and 5 per cent. from the lower end.

In case any other method is proposed for producing the solid gun ingots, its acceptance will be conditioned upon the rule that the part of each which is to be delivered for test and acceptance must be equal in quality and in all other respects, to a gun ingot cast solid in the usual way, from which at least 30 per cent. of the weight of the ingot has been discarded from the upper end and 5 per cent. from the lower end.

The weight of the original ingot will remain as above, whatever method of forging is employed.

Ingots must be free from imperfections that would injuriously affect the finished forging or gun.

For tubes, plugs, and mushrooms, each ingot will be reduced in diameter, by forging, at least 50 per cent. at the largest diameter of the piece, and at no point less than this. For jackets, each ingot will be reduced in diameter, by forging, at least 40 per cent. at the largest diameter of the jacket, and at no point less than this.

In case tubes are forged on a mandrel from bored ingots, the walls of the ingots at all points must be reduced in thickness, by forging, at least 50 per cent. In case jackets and hoops are forged in the same way, the walls of the ingots at all points must be reduced in thickness, by forging, at least 40 per cent.

In case hoops are forged from solid ingots by upsetting and punching and subsequent elongation or enlarging on a mandrel, the walls at all points must be reduced in thickness, by forging on the mandrel, at least 33 per cent.

Ingots must be forged down to within the following dimensions of finished diameters:

Tubes and jackets, 6 inches calibre, to within 2 inches.

Tubes and jackets, 8 inches calibre, to within 2½ inches.

Tubes and jackets, larger guns, to within 3 inches.

Plugs and mushrooms, to within 2 inches.

Hoops, inside and outside, to within 2 inches.

The following exceptions will be made to the above rules:

The rear end of each tube will be forged on a prolongation of the part over the powder chamber, the steps not being followed. The front end of the jacket will be forged in prolongation of the body, the reduced diameter at that point not being followed. All hoops will be forged as plain, hollow cylinders.

The lower end of each ingot, as cast, will be the breech end of the forging made from it.

It will be necessary for the contractor to leave forgings long enough to get test specimens beyond the finished dimensions.

Forgings will be rough-bored and turned to dimensions as near to finished sizes as shown below. In this work the general lines only of the finished piece will be followed, not angles nor corners.

The bore of tubes will be one plain cylinder.

The bore of the jackets will be on two diameters—that for the screw-box and that for the main body; these two will be joined by an easy slope.

Tubes, 6 inches, and 8 inches, outside and inside, to within ⅜ inch on the radius.

Tubes, 10 inches to 12 inches (both inclusive), outside and inside, to within ½ inch on the radius.

Jackets, 6 inches and 8 inches, outside and inside, to within ¼ inch on the radius.

Jackets, 10 inches to 12 inches (both inclusive), outside and inside, to within ⅜ inch on the radius.

All other forgings are to be rough-bored and turned to within ⅛ inch on the radius, outside and inside.

Hoops are to be rough-bored and turned as plain hollow cylinders.

The shank of the mushroom is to be joined to the head with a radius.

One-eighth (⅛) of an inch (for machine facing) must be left on the ends of all forgings, except tubes and jackets; on those, ¼ inch will be left.

Forgings are to be annealed, oil-tempered under such conditions as will assure their resistance, and again annealed. No piece will be accepted, nor will its test specimens be broken or considered, unless the last process has been an annealing one. The forging must be left with a uniform fine grain.

All pieces forged solid must be annealed and otherwise treated after being rough-bored and turned to the above dimensions. Pieces forged on a mandrel may be annealed before being rough-bored and turned. Hoops, whose forged thickness is less than 4 inches, may be treated and tested before being rough-bored and turned.

The contractor must deliver each forging and casting in such condition as to allow of its being finished true and to the dimensions that were standard at the time said piece was rough-bored and turned, ordinary care being exercised in machine work.

If the inspector finds that any part of a forging has received less hammering or other beneficial treatment than it should properly have received, as compared with the parts from which test-bars are to be taken, the piece will be rejected.

After the final forging, all heating must be uniform or uniformly graded throughout the entire piece; and all heating for tempering and all immersing shall be executed with the forging in a vertical position. The whole of the piece must be subjected to the treatment at the same time.

The contractor shall state for each piece, in writing, the exact treatment it has received.

The inspector shall examine all fractures of the metal, in the course of manufacture, for the purpose of determining whether it is of uniform and homogeneous structure.

TESTS AND ACCEPTANCE.

These tests are to be made on cylindrical specimens two inches long between measuring points, one-half inch in diameter. The specimens are to be taken from the forgings after final treatment, *transversely to the axis of the bore of the finished gun*, and within the finished section prolonged. They are to be taken as near the finished piece as practicable, leaving sufficient metal for submitting additional test-bars in case of retreatment.

Test-bars shall be cut, and tests made under the supervision of an agent or inspector of the Department, who may make the tests personally if he should so desire. He will stamp and have the custody of each test-bar.

The tests shall be made at the works of the contractor, and at his expense; and he shall provide a testing-machine of a pattern approved by the Department, and capable of exerting a strain of 100,000 pounds.

The following tables of specifications indicate certain limits of physical qualities that may be shown by tensile specimens upon which the acceptance or rejection of forgings and castings will be based, according to the rules given below:

TABLE 1.—*6-inch and 8-inch guns.*

	Tubes.			Jackets.		
	A.	B.	C.	A.	B.	C.
Tensile strength..........pounds..	80, 000	72, 000	70, 000	85, 000	76, 500	74, 000
Elastic limit..........do....	38, 000	34, 000	33, 000	40, 000	36, 000	34, 000
Elongation..........per cent..	22	20	12	20	18	12
Contraction of area..........do....	35	20	15	30	20	15

TABLE 2.—*10-inch and 12-inch guns.*

	Tubes.			Jackets.		
	A.	B.	C.	A.	B.	C.
Tensile strength..........pounds..	80, 000	72, 000	70, 000	85, 000	76, 500	74, 000
Elastic limit..........do....	38, 000	34, 000	33, 000	40, 000	36, 000	34, 000
Elongation..........per cent..	20	18	12	18	15	10
Contraction of area..........do....	30	20	15	30	20	12

TABLE 3.—*For all calibres.*

	Hoops.			Trunnion bands.		
	A.	B.	C.	A.	B.	C.
Tensile strength..........pounds..	100, 000	90, 000	90, 000	90, 000	80, 000	80, 000
Elastic limit..........do....	50, 000	45, 000	45, 000	40, 000	36. 000	36, 000
Elongation..........per cent..	18	16	12	12	10	6
Contraction of area..........do....	30	25	15	15	12	8

TABLE 4.—*For all calibres.*

	Plugs.			Mushrooms.		
	A.	B.	C.	A.	B.	C.
Tensile strength..........pounds..	80, 000	72, 000	70, 000	65, 000	60, 000	60, 000
Elastic limit..........do....	38, 000	34, 000	33, 000	30, 000	27, 000	27, 000
Elongation..........per cent..	20	18	12	25	22	12
Contraction of area..........do....	30	20	15	35	25	15

The contractor shall first present three specimens from each end of a tube or jacket, and from the end nearest the upper end of the ingot or casting of each hoop, plug, or trunnion-band; and from mushrooms, two transverse specimens from the head and one longitudinal specimen from the stem. The central axis of these longitudinal specimens from the mushroom stem need not be nearer the central axis of the forging than one-half of the radius of the latter.

After a piece is cut or otherwise detached from a forging, no specimen from the piece will be considered if the latter has received any treatment after being detached as aforesaid.

In case the results obtained from the first submission do not conform to the specifications, and in case the contractor is of opinion that the quality of the metal will be improved by retreatment, he may retreat the forging or casting, and submit additional specimens, and the results obtained from the former specimens will no longer be considered.

If during powder proof, after the completion of a gun, any forging therein shall fail on account of the presence of flaws, slag, cavities, or foreign substances in number or quantity serious enough to be clearly the sole cause of such failure, the forging shall be replaced by the contractor. The proof-rounds to which this rule applies shall not exceed five. Forgings are not *finally accepted* until they have borne this test.

DELIVERY.

The forgings for each calibre of guns must be delivered, completely tested, in sets, each set to include all the parts going to compose a complete gun. Sets must be delivered within the times given on the following table, subject to the qualifications regarding rejected pieces. The forgings may be made by the contractor in such order as he sees fit, and they may be examined by the inspector during manufacture, and tested when completed; but they must be *delivered* in the order and within the times shown below.

The delivery of gun-forgings must commence within three months after the completion of an adequate plant.

As it is well known that no such plant exists now in the United States, it becomes necessary to have from the successful bidder, within fifteen days after notification that his bid has been accepted and before the execution of the contract, evidence satisfactory to the Department that actual provision has been made for securing such plant within two and a half years.

In making contracts for the gun steel to be delivered to the Navy, the contractor is allowed two and a half years for completing his plant. The time, including this allowance, in which the different sets of forgings are to be delivered is given in a table issued from the Naval Ordnance Bureau and summarized below:

Six-inch. Number of sets, 46; delivered from the thirty-third to the forty-eighth month.

Eight-inch. Number of sets, 4; delivered from the thirty-sixth to the forty-second month.

Ten-inch. Number of sets, 24; delivered from the thirty-ninth to the fifty-fourth month.

Twelve-inch. Number of sets, 2; delivered from the forty-second to the fifty-fourth month.

The premium will be 1 per cent. per month on the price per ton of the various exhibits going to make up a complete set of forgings for any one gun. The delivery of a set of forgings will (for the purposes of the computation of premiums) be reckoned from the day that a successful set of specimens are presented to the inspector from the last forging which goes to make up the complete set of forgings of the gun whose time of delivery is in question. Less time than ten days shall not be reckoned, ten days to twenty days shall be reckoned as one-half month, and more than twenty days shall be reckoned as one month.

INSPECTORS, ETC.

The Department shall have the right to keep agents or inspectors at the works, who will have free access to all parts thereof, and who will be permitted to examine freely the raw material, to witness all the processes of manufacture, and to examine all the contractor's records with reference to such matters.

The weights of delivered material will be determined, to the nearest 1,000th of a ton, by calculation of the volumes of the rough-bored and turned pieces from the drawings, which shall always show the allowances above finished dimensions. The weight of a cubic inch of steel will be assumed to be 0.28330 pounds; 2,240 pounds equal one ton.

All pieces must be delivered rough-bored and turned *within* the dimensions allowed, and they will be measured and callipered at the expense of the contractor, to satisfy the inspector that the dimensions have not been exceeded.

The bids for the gun forgings (1,221 tons in all) called for by the Navy Department were opened on March 22, 1887, and were as follows: Cambria Iron Company, $851,513.90; Bethlehem Iron Company, $902,230.79; Midvale Steel Company, $1,397,240.

In view of the terms of the proposal inviting manufacturers to bid for both armor plates and gun forgings, the contract has been awarded to the Bethlehem Iron Company as being the lowest bidder for the entire order, and the Bethlehem Company has expressed its willingness to furnish the gun forgings at the price of the lowest bidder (Cambria), and at this price the contract will be filled.

GUN-TRIALS.

8-INCH STEEL B. L. R. FOR THE UNITED STATES ARMY.

In March, 1883, Congress authorized the construction of an 8-inch B. L. R., to be built entirely of steel, and under the direction of the Ordnance Department, for use of the Army. It was found that it would be impossible to build the gun entirely of domestic steel, and the forgings for the tube, jacket, and trunnion hoop were therefore ordered from the firm of Sir Joseph Whitworth & Co., England; the remaining parts were supplied by the Midvale Steel Works.

The machining and assembling were done by the West Point Foundry. The material was all delivered by February, 1885, and in June, 1886, the gun was ready for a firing trial.

The design of the gun is, in the main, similar to that of the 8-inch B. L. R. for the Navy. It has, however, a greater number of hoops, and the system adopted for locking the tube and jacket and for transferring the longitudinal strain to the trunnions differs materially from that employed in the Navy gun.

In the Army gun the jacket is pierced at its forward end by four radial holes. In these are placed stout pins (secured by a screw), which project into the tube, thus preventing longitudinal and rotary motion between the tube and jacket. A shoulder on the outer surface of the jacket fits a corresponding one on the inside of the last "A" hoop, which in turn abuts against the trunnion band. The latter is shrunk on as the other hoops are, while in the Navy gun it is screwed on cold. The original design of both guns left the tube unsupported for a considerable portion of its length, but both have since been hooped all the way to the muzzle.

The Army 8-inch gun was designed for firing a projectile of 285 pounds weight with 100 pounds of powder, though these figures will most likely be increased so that the projectile will weigh about 300 pounds and the charge about 113 pounds, while the pressure in the chamber will not pass a maximum of 16 tons per square inch.

Before the additional chase hoops were put on 24 rounds were fired with several qualities of powder and with various weights of shot. The results of 7 representative rounds of this trial appear in the following table:

Ballistic results.

Kind of powder.	Weight of charge.	Projectile.	Velocity at 150 feet from muzzle.	Pressure per square inch.
	Pounds.	*Pounds.*	*f. s.*	*Pounds.*
Rottweil-Hamburg	100	182	2, 135	29, 450
	100	235	1, 933	32, 150
	100	286	1, 787	32, 800
Du Pont's P. A	100	235	1, 929	32, 950
Du Pont's:				
P. A	100	286	1, 812	35, 450
P. I	100	286	1, 702	26, 425
P. K	100	235	2, 017	37, 662

ACCURACY OF FIRE.

In firing two series of five shots each at a target 3,000 yards distant to determine which of two different forcing bands submitted for trial, was of the better width, the following results were obtained with the band adopted:

Target 30 *by* 40 *feet—range* 3,000 *yards.*

	Feet.
Mean vertical deviation from centre of impact	1. 90
Mean horizontal deviation from centre of impact	1. 56
Mean deviation from centre of impact	2. 46

or the centres of all the shot-holes were contained within a circle of 6½ feet diameter, which denotes a very high degree of accuracy.

During this trial the most careful attention was given to noting the increase in diameter of the bore from stretch of metal, especially to that point of the chase unsupported by hoops. The gun was carefully gauged after the first, fourth, seventh, thirteenth, twenty-third, and twenty-fourth rounds. After the thirteenth round the greatest increase of diameter of bore in the chase was only $\frac{2}{1000}$ of an inch, while the maximum enlargement at the conclusion of the firing was $\frac{6}{1000}$ of an inch, and this small amount was found at a distance not greater than 12 inches inside the muzzle; so that it may fairly be said that the gun as originally designed had sufficient strength for any ordinary service. But the yielding of the metal, while it did not render the gun in any degree unserviceable, indicated the advisability of continuing the hooping to the muzzle, especially as it was the intention to continue the trial until the gun fails entirely. Consequently, after the twenty-fourth round the the gun was returned to the factory and the additional hoops placed upon it.

The weight of the piece has been thereby increased from 13 tons to 13½ tons, and the enlargement of the bore from the first twenty-four rounds has entirely disappeared.

In fact the tube began to return to its original diameter as soon as a small part of the exterior had been removed for the reception of the hoops, showing that the tube had not been sufficiently annealed, and that a part of the stretch of the metal was undoubtedly due to this fact. The gun as thus completed was returned to Sandy Hook for a continuation of the trial, which began March 4, 1887. Up to the present time thirty additional rounds have been fired, making in all fifty four, and thus far no accident or failure of any kind has occurred, although at times the pressure in the chamber has reached 21 tons per square inch.

A fair estimate of the power of the piece may be derived from a study of the annexed table, containing the results of four representative rounds taken from the last trials:

Date.	Charge.		Shot.	Density of loading.	Velocity.	Pressure.	Energy.
	Kind.	Weight.					
1887.			*Lbs.*		*Feet.*	*Lbs.*	*Foot-tons.*
Mar. 4	German	110	250.8	0.98	1,986	35,800	6,857
4	do	110	302.	0.98	1,857	37,000	7,219
4	do	110	289.	0.98	1,875	35,900	7,043
4	Du Pont's P. N	110	289.	0.98	1,878	36,000	7,066

The object now to be attained is to reach the greatest energy with a maximum chamber pressure of 36,000 pounds per square inch. The charge of 110 pounds of Du Pont's P. N. powder seems to fulfill these conditions better than any other brand that has thus far been tested, and a considerable quantity has therefore been ordered for the continuation of the trials, though it is probable that the domestic powder will be even further improved so that a charge of 113 pounds may be used without passing the limit of pressure of 16 tons, with a projectile of 290 or 295 pounds.

TRIAL OF THE 110-TON ELSWICK B. L. R.

The trial of this gun, which is the heaviest piece of ordnance ever constructed in England, began at Woolwich February 10, 1887. Two guns of this size have been built, and they will form part of the armament of H. M. S. Benbow. They are built entirely of steel, and consist of a tube (one forging), a jacket in which the breech-block is secured, and forty-one hoops. There are no trunnions, the gun being supported in a saddle and held in place by bands on the gun which rest in corresponding grooves in the saddle; a strap passing over the gun is bolted to the saddle on each side, thus holding the gun down in place. The longitudinal strain is transferred through a system of shoulders to the saddle bands in a similar manner to that of the U. S. Navy 8-inch rifle.

The obturation is peculiar to this calibre. It is not the Elswick cup nor the De Bange asbestos pad, but a modification introduced by Mr. Vavasseur, wherein the mushroom of the De Bange system is retained, but the asbestos is replaced by a ring of soft copper which is forced by compression on the discharge of the gun into close contact with the walls of the chamber.

The dimensions of the 110-ton guns are as follows:

Total length	inches	524
Length of bore (30 calibres)	do	487
Length of rifling	do	397
Diameter of bore	do	16.25
Diameter of chamber	do	21.125
Cubical capacity of chamber	cubic inches	28,610
Weight of gun	pounds	247,795
Weight of projectile	do	1,800

The system of rifling is that known as the polygroove; the increasing twist begins with one turn in 120 calibres and ends with one turn in 56 calibres.

The powder used during the trial was the Waltham Abbey "Prism Brown," or "Cocoa," the charges being subdivided into parts weighing from 112 to 150 pounds to facilitate loading. These charges are contained in silk cartridge-bags. The accompanying table gives all the particulars of the first four rounds:

No. of round.	Weight of powder charge.	Weight of projectile.	Muzzle velocity, f. s.	Mean pressure in tons per square inch.	Total energy at muzzle.	Energy per ton of weight of gun.
	Pounds.	*Pounds.*			*Foot-tons.*	
1	600	1,800	1,699	9.65	36,050	328
2	700	1,800	1,843	12.05	42,390	385
3	800	1,800	2,007	15.00	50,260	487
4	850	1,800	2,078	18.75	53,927	490

The service-pressure for these guns is set at 17 tons per square inch. The high pressure of 18.75 tons, which was reached at the fourth round, was due to the use of a different powder—"Westphalia Prismatic No. 1 Brown," the prisms being 1¼ inches across hexagonal faces by 1 inch in length.

At a later date the trials were continued and additional rounds were fired with the following results:

No. of round.	Kind of powder.	Charge.	Velocity at muzzle f. s.	Pressure in the bore in tons per square inch.
		Lbs.		
5	Prism Brown...	850	2,142	19.5
6	Waltham Slow..	950	2,104	15.7
7	Prism Brown...	850	2,150	19.9
8	Waltham Slow..	1,000	2,128	16.1
9	do	1,000	2,128	16.2

These are probably the heaviest powder charges ever fired, and the results are regarded by the English as highly satisfactory, as they well deserve to be, for the gun has developed very high power, and though subjected to excessive pressure has shown no weakness and is reported as in perfect condition. The strength of the piece is estimated at about 30 tons per square inch, so that the practice thus far has been well inside of the limit of strength. Like all the new high-powered steel guns the greatest deterioration will come from erosions in the bore, as it is not probable the elastic limit of the metal will ever be reached.

The immense power derived from the large charges used in the proof of this gun is well shown by the recoil of the piece.

The gun was mounted on a special testing carriage of 95 tons weight, supported by six pairs of trucks running on inclined rails. At the first round the recoil was from 50 to 60 feet. Upon increasing the charge of powder to 850 pounds at the third round the recoil was 77 feet.

The gun has not yet been tested for penetration, but with 900 pounds of powder a projectile weighing 1,800 pounds should have a penetration of about 34 inches of wrought iron at 1,000 yards.

TRIAL OF THE 119-TON KRUPP GUN.

This is the heaviest gun ever constructed. The manufacturer has delivered three (of a contract for four) to the Italian Government, one gun being retained for a time to continue experiments with powder.

The general dimensions of the gun are as follows :

Calibre	inches	15.75
Length of bore, 35 calibres	do	551.2
Length of rifling, 31.8 calibres	do	499.7
Lands and grooves	number	92
Depth of grooves	inches	0.079
Total weight ot gun	tons	118¼
Weight of breech mechanism	pounds	8,290

Ammunition.

Length of projectile, 3.2 calibres	inches	50.39
Length of head, 1.32 calibres	do	20.83
Diameter	do	15.669
Weight	pounds	2,028
Powder charge, in five parts	do	727.5

The report that these guns had failed at proof is believed to be without sufficient foundation, as all the official statements in connection with the trials affirm that all the guns have been accepted. The most emphatic denial of the report comes in the shape of a reply from the Krupp firm to a letter from U. S. Consul J. S. Potter (published in Army and Navy Register, December 18, 1886), asking for information on this subject. In the reply Krupp says, "In *none* of these four guns has the slightest defect been traced; on the contrary, even No. 19464 (one of these guns), which has fired 82 rounds, partly with considerably increased charges, is in *completely fit state for any service.*"

During trial the rounds fired were as follows: First, 16 rounds were fired for the purpose of selecting a suitable powder, after which the first gun fired 50 acceptance rounds, making 66 in all. The second gun was fired 12 times; the third, 11 times, and the fourth, 12 times.

The powder trials resulted in the selection of the "Duneberg" prismatic powder, with which it was found that the required energy of 45,206 foot tons could be obtained with the 2,028-pound projectile by using 727 pounds of powder, while the pressure developed in the chamber did not exceed 15.74 tons per square inch. This loading was consequently retained for all the rounds beyond the nineteenth.

The trials took place on the proving grounds at Meppen, beginning August 31, 1886, and ending September 28, 1886. All the stipulations of the contract were fulfilled These required that one gun should fire at least 50 rounds with projectiles of 2,028 pounds, and attain a muzzle velocity of 1,804 f. s., and a muzzle energy of 45,206 foot-tons. Ten of the 50 rounds were to be fired at a target, distant 2,734 yards, and at least 15 rounds at a target 5,466 yards; the remaining rounds were to be fired at various ranges. As regards accuracy, it was stipulated by the contract that at the range of 2,734 yards the shot must all strike a vertical square of 10.66 feet side, while the *longitudinal* dispersion must not exceed 262 feet, The corrected ranges obtained with different angles of elevation up to 18°, which is the greatest that can be reached with the mounting, is given in the table below:

Elevation.	Range.
° ′	*Metres.*
2 29	2, 432
2 32	2, 450
3 37	3, 497
3 54	3, 965
5 21	4, 996
7 27	6, 588
10 30	8, 407
14 15	10, 438
18 00	12. 130

The accuracy of fire at 2,500 metres (2,734 yards) was excellent; the 9 rounds fired gave only 1.1 metres of vertical and 2 metres lateral deviation.

The report upon the trial concludes with the following summary: The four 40-centimetre guns, 35 calibres long, tested, answered all requirements in every respect. Gun No. 19,464, with which 66 rounds had been fired, showed, as was to be expected after firing so many rounds with a charge of 330 kilograms (727 pounds) from a gun of large calibre, the beginning of erosions, which are, however, so slight that the chamber has not been affected.

In order to test the effect of brands of powder other than those previously used the firing was continued up to 82 rounds.

During these trials velocities of 1,804 and 1,824 f. s. were reached with 16.5 to 17.65 tons pressure per square inch in the chamber, using a charge of 793.67 to 826.74 pounds, respectively. Round 81 was fired with 864.57 pounds of powder, when the chamber pressure rose to 18.86 tons per square inch, and the velocity was increased to 1876 f. s. On the 80th round a pressure of 19.52 tons was reached with a charge of 846.57 pounds, which gave a velocity at the muzzle of 1,899 f. s., corresponding to an energy of 58,122 foot-tons. The pressures reached with the last two rounds were not regarded as excessive nor as reaching a limit that would subject the piece to an injurious strain, so that the battering charge will most likely be set at about 825 pounds.

At the conclusion of 82 rounds the piece was carefully examined and showed no material damage, the length of chamber before trial being 92.99 inches and at the end of the experiments being only 93.03 inches, or an increase in length of but .04 of an inch. The penetration at the muzzle for the heavy loading of the last two rounds is claimed to be about 40.9 inches of wrought iron, which is believed to be greater than any power yet developed, and to be excessive; but if we compare this and the 110-ton Elswick gun with the loading that each had at the proof firing, we find that the English gun developed greater power on less weight.

Name of gun.	Weight.	Powder charge.	Weight of projectile.	Muzzle velocity.	Muzzle energy.	Remarks.
	Tons.	*Lbs.*	*Lbs.*	*f. s.*	*Foot-tons.*	
Elswick	110	850.	1, 800	2. 078	53, 927	Proof trials.
Krupp	119	727. 53	2, 028	1, 804	45, 206	
Elswick	110	1000.	1, 800	2, 128	57, 680	Best results.
Krupp	119	846. 57	2, 314. 8	1, 899. 5	58, 122	

ZALINSKI'S PNEUMATIC GUN.

During the past year the trials of this gun have been so successful, and its power and accuracy have been so much increased, that it bids fair to prove an important factor in coast-defense and naval warfare.

Much of the adverse criticism upon this system is due to a comparison of its powers with those of high-power rifled ordnance. This is a mistake which many fall into, for the dynamite shell is essentially a torpedo, while its gun is simply a safe means of imparting high velocity to violent explosives.

The only piece of ordnance which is in any way similar to the pneumatic gun is the mortar, the accuracy and power of which is excelled by the pneumatic gun. When fired from a fixed platform the accuracy of the pneumatic gun is excellent; but when used on shipboard the motion and variable trim of the vessel will greatly increase variations of fire. It will, however, be an important addition to existing weapons of naval warfare. Comparing the power of this with other torpedo systems the following advantages are claimed:

(1) The explosive charge bears a greater proportion to the total weight of projectile than in any other system.

(2) The ordinary range of submarine torpedoes does not extend beyond 800 yards, while their effective range is about 400 to 500 yards. The pneumatic gun has given a range of 3,860 yards, and very accurate practice has been accomplished at ranges up to 1,600 yards.

(3) Even at the short range of 400 yards the submarine torpedo, of the most rapid type, will be at least 45 seconds traversing this distance, while the aerial torpedo, or dynamite shell, will accomplish it in less than 2 seconds, so that it is impossible to avoid the latter, while it is stated that torpedoes have been avoided by the use of the helm.

(4) Rapidity of fire. The pneumatic gun has discharged as many as 5 shells containing 50 pounds of dynamite in 9 minutes 40 seconds. A submarine torpedo carrying a charge of 50 pounds weighs between 500 and 600 pounds, and not more than two or, at the most, three could be fired from one tube in the time that the pneumatic gun discharges five.

(5) The chance of inflicting damage to vessels by the dynamite shell is greater than by a submarine torpedo. With the latter only the bottom is exposed, while with the former the deck and sides are equally open to attack.

(6) In order to discharge a submarine torpedo with any chance of success the vessel carrying it must approach the enemy within 400 yards, thus subjecting itself to the destructive fire of machine and rapid-fire guns, while vessels carrying pneumatic guns can use them with accuracy at 1,000 yards greater range, and avoid much of the deadly effect of light rapid-fire guns at short ranges.

On the other hand:

1. With an estimated range the chances of hitting, as in all mortar fire, are greatly reduced by the high curve of trajectory as compared with those of high-power guns, or auto-mobile torpedoes, in which, for moderate ranges, lateral training is almost the only element in correct sighting.
2. When used afloat the inaccuracy above referred to is greatly enhanced by any slight motion or change of trim of the vessel.
3. The gun is extremely vulnerable from the fire of small arms or machine guns, unless placed entirely below water, which arrangement requires a great amount of space.

The system is of undoubted value as a means of countermining.

One of the many valuable features of the dynamite shell used with the pneumatic guns is the electric primer, a short description of which was given in last year's publication of this office.

During the year just passed this primer has been greatly improved in uniformity of action, and is now said to be safe and reliable; it can be tested before placing it in the projectile, and is inoperative until it leaves the gun. All-metal projectiles have been designed which have a spiral feather on the tail which imparts rotation to the shell, and increases its range.

Firing trials.—For determining various points in construction and for experiments before the naval board, the pneumatic 8-inch gun has been fired 14 times. The following table, prepared and furnished by Lieutenant Zalinski, contains a full and accurate history of the trials:

Date.	No. of fires.	Weight of projectile.	Weight of charge.	Initial pressure.	Final pressure.	Position of centre of gravity.	Loss of pressure.	Elevation.		Sight allowance points.		Deviation (yards).		Range.	Time of flight (seconds).	Valve setting.
										Right.	Left.	Right.	Left.			
1886.		*Lbs.*	*Lbs.*	*Lbs.*	*Lbs.*	*In.*	*Lbs*	°	′					*Yds.*		
June 26	1	130½	Loaded with sand.	1,005	955	13⅝	50	10	40	10	....	5.3	......	1,613	8.5	1.1
26	2	130¼		1,000	950	13⅝	50	10	40	6	....	......	2.7	1,620	8.5	1.1
26	3	130¼		1,003	953	13 9/16	50	10	40	6	....	......	3.0	1,613	8.5	1.1
26	4	130¼		1,000	950	13 9/16	50	10	40	6	....	......	7.3	1,613	8.5	1.1
26	5	130¼		1,000	950	13¼	50	10	40	6	....	......	5.3	1,613	8.5	1.1
Nov. 9	1	141	50	1,000	895	13⅝	105	20	30	10	....	Not taken. Most of these shots almost perfect as to line.		2,860	15.7	0.85
9	2	148¼	51¾	1,004	895	......	109	20	30	8	....			2,940	15.4	0.9
9	3	140½	49¼	1,003	926	12 13/16	77	20	30	7	....			2,600	......	1.0
1887.																
Mar. 12	1	139¼	50	1,000	950	12 21/32	50	14		0	0			1,920	9.9	1.5
12	2	136½	50	1,000	930	12⅞	70	14		0	0			2,612	11.2	1.0
26	1	146	50¾	1,002	955	13½	47	14		0	0			1,816	9.6	1.5
26	2	144	50⅓	1,001	933	12½	67	14		0	0			2,492	11.8	1.0
26	3	143	50½	1,005	905	12⅝	100	33	30	0	0			2,456	20.8	0.8
26	4	139¼	50	1,005	905	14⅛	100	33	30	0	0			3,868	25.4	0.8

The firing of June 26 was for the U. S. Naval Board, of which Capt. John A. Howell, U. S. N., was president. The series was to test the accuracy of fire. The wind was from left to right; force from 12 to 15 miles an hour. The sight allowance given (10 points) was equivalent to 16.1 yards. This appearing to be too great the gun was resighted with only 6 points, equal to 9.7 yards. No change was made thereafter. Allowing for this, the maximum lateral dispersion of the five rounds was 6.2 yards, while if only the last four rounds are considered the maximum dispersion was 4.6 yards. The maximum dispersion in range was only 7 yards, and four of the five shots had exactly the same range.

Although the loading was done by untrained men, and no great effort was made to secure rapidity of fire, the five rounds were discharged in nine minutes and forty seconds.

The object of the trials on the 9th of November was to test the value of the valve settings, which had been changed. The flight of the first projectile was not quite smooth. The delayed-action primer exploded on the bottom in deep water. The quick-action primer used with the second round exploded. At the third fire the tail of the projectile broke, and the flight was irregular. The delayed-action primer exploded on the bottom in shoal water.

The trial of March 12 was to demonstrate the control over the range by varying the "cut off" adjustment of valve, pressure and elevation remaining the same, as also to show control over the time of explosion by the character of the fuse used. It will be seen that the loss of pressure was changed 20 pounds and the range increased 692 yards. The quick primer of the first round exploded near the surface. The delayed-action primer of the second round exploded after disappearing under water and about 40 feet from the place where it was last seen.

The trial of March 26 was mainly to determine the relative merits of double and single knobbed projectiles; the elevation, pressure, and valve-setting remaining the same as on March 12 for the first two rounds, while the elevation and valve-setting for the last two were changed, the pressure remaining practically the same, though slightly increased. In the first round the shell was fitted with a quick-action primer which exploded on complete submersion. The second shell had a delayed-action primer. This shell ricochetted 536 yards and exploded when buried. The third projectile was fitted with a quick primer, which exploded on entering the water. The short range of this fire was probably due to the breaking of the tail in firing. The fourth shell had a long delayed-action fuse in the head. The shell fell in shoal water and did not explode. This failure was said to be caused by the head being broken off by striking the bottom before the primer had time to act.

NEW DEVELOPMENTS IN ORDNANCE.

The De Brnyk gun.—Under this name has lately appeared a new weapon, the contruction of which has not been made public. The main feature of advantage claimed for it consists in the readiness with which it can be taken apart and assembled. This renders the transportation of large calibres easy, permitting the use of heavier siege guns than could be otherwise used. Each calibre is divided into four principal parts, viz, a tube or core, a jacket carrying the trunnions, a hoop for connecting the parts, and a chase hoop or nut as it is termed by the inventor. The core or tube is strengthened by chase hoops. The jacket is of the usual length and is fitted to receive the breech-closure; on the forward end a thread is worked. The nut is a hoop placed just forward of the trunnion band. When the gun is assembled, cold, the trunnion band is screwed upon both jacket and nut, binding them together and thus completing the gun structure.

A slight taper to the parts is sufficient to bind them firmly together when the nut is screwed into place.

A 6-inch gun of this system lately tested at Ochta has given excellent results, 860 rounds having been fired without accident. The scoring is now considerable, but not sufficient to make the gun unserviceable, it being considered that the piece will stand about 200 more rounds before the erosions are sufficient to require the chamber to be reamed out. Another peculiarity of this system is that the tube may be turned as desired in the jacket, and so vary the effect of erosions.

New Krupp gun.—The reports upon new gun constructions are to the effect that Krupp has under manufacture a gun weighing about 139 tons. The calibre will be 15.7 inches and the total length 52½ feet. The projectiles are of two sizes; one 45 inches long, weighing 1,630 pounds, and the other 62 inches long, weighing 2,314 pounds. The charge, which is the same for each projectile, weighs 1,069 pounds.

The penetration in wrought iron at the muzzle for the two shells is estimated at 45 inches for the lighter and 47½ inches for the heavier. It is also reported that it is proposed to manufacture at the same works a gun weighing 150 tons, of 17½ inches calibre, and throwing a shell of 3,360 pounds weight, and length about 6 feet.

The Hope 12-pounder gun will soon be tested on the proving-ground, under the direction of the naval ordnance department of the British admiralty.

As the claims of the inventor are far in excess of any of the results yet obtained with similar guns, the dimensions and a few particulars will be given: Length of gun, 10 feet; length of chamber, 45.5 inches; calibre, 2 inches; diameter of chamber, 3.1 inches at breech and 2.4 inches at seat of shot; weight of shell, 6 pounds.

After the gun has been tested under these dimensions they will be changed as follows: Diameter of bore increased to 2.5 inches; length of chamber increased to 53 inches; weight of shell increased to 12 pounds.

The thickness of the walls of the gun is the same for the whole length of the piece.

The charge is ignited upon the well known Hope system; that is, the entire charge, which is of rapid-burning powder, is ignited as nearly as possible at the same instant along its entire length. This is accomplished by means of a small tube, extending the whole length of the cartridge, filled with fine powder. This tube is pierced with holes so that the flame reaches the charge at the forward and rear ends at the same instant.

The discharge of the powder in the small tube also sets the shot in motion so that the explosion of the charge does not encounter the dead weight of a shot at rest. It is calculated that the muzzle velocity will be about 4,500 f. s.

Should the trial of this piece result successfully, the construction of ordnance will be materially changed, for the principle upon which the gun is constructed is at variance with all modern practice and science of gunnery.

The Canet gun-carriage is the latest development in the mounting of ordnance. It is a central pivot mounting and in appearance is similar to the Vavasseur. Three of these mountings have been placed in the new dispatch-boat for Hayti, the Toussaint L'Ouverture, one being forward of the foremast and one on each beam; the forward one, carrying a 16-centimetre (6.3-inch) Canet gun, has a lateral train of 236°, with a depression of 7° and elevation of 28°. The broadside guns on the same mountings, in sponsons, have a lateral train of 165°, 3° depression, and 28° elevation. This is a wide range and in advance of any other mounting as yet made public, especially as regards elevation; in this particular 20° has heretofore been considered about the maximum.

RAPID-FIRE GUNS.

This system, which is just now so important an adjunct to the main battery of ships of war, is of but recent development. The first order received for a weapon of this kind by the Hotchkiss firm came from the United States, and the guns now mounted in the new ships Boston, Atlanta, and Dolphin were delivered under it. Three calibres were obtained, viz, the 6, 3, and 1 pounder, as they are known in the United States Navy, their usual names in other countries being the 57, 47, and 37^{mm} guns. Since their introduction the demand for larger calibres, by most of the prominent naval powers, has been so pressing that the Hotchkiss Company has produced a 9-pounder and has a 33-pounder in course of manufacture. It is believed that this last calibre represents about the limit of utility of the Hotchkiss system, though the gain in time by the use of ammunition carrying the charge [illegible] projectile, and fulminate in one case will recommend it for use with much larger calibres, even where two men may be required to handle the cartridge.

During the year just past some important trials have taken place with guns of this class.

The various systems now in use, or being developed, are given below in alphabetical order: Albini, Armstrong, Driggs-Schroeder, Gruson, Hotchkiss, Krupp, Maxim, Nordenfelt. Of these the Armstrong has not been favorably received on account of the cumbersome breech-closing arrangement. This consists in two side levers attached to and turning about the trunnions; a cross-head connects the two levers, and by an eccentric motion one of them is pressed against or removed from the breech of the gun, thus closing or opening it. The Bausan has two of those guns, but with that known exception few, if any, have been put in service.

The Gruson gun is said to be very similar to the Hotchkiss in its mechanism, though not as good. The Maxim and Hotchkiss are both well known. The Nordenfelt, which in Europe is the greatest rival of the Hotchkiss, is entirely different from the guns heretofore made under this name. In the single-shot rapid-fire gun the breech is closed with a double breech plug, which is revolved in the breech recess by a cam motion. The plug is divided transversely, the front half carries the firing pin, and has only a circular motion in closing and opening. The rear half acts as a wedge, the first motion being downward and the second circular, the front half then moving with it.

One of the most complete tests to which guns of this class have been subjected was that which was conducted by the Italian Government, at Spezia, in February of last year. The results appeared in the "General Information Series, No. 5," p. 7.

In order to compare the different systems and the results of different trials, the Spezia and subsequent tests are represented on the accompanying plate.

The Hotchkiss and Nordenfelt guns were tried in competition at Ochta, near St. Petersburg, in September last. The reports that have reached this country are very meager, but are unanimous in favor of the Nordenfelt gun. From what can be learned the fire was first for rapidity, in which the Nordenfelt discharged 30 rounds in one minute, and the Hotchkiss 20 rounds in the same time. The initial velocity of the former being 624 metres (2,047 feet) per second, while that of the latter was 548 metres (1,797 feet) per second.

The fire of both guns was directed upon a target at 1,800 metres (1,969 yards) range. The Nordenfelt scored 9 hits, while the Hotchkiss made none. It is more than likely that this failure was due more to defective pointing than to any defect of construction.

The trial closed with a very interesting and instructive experiment.

Four targets were placed at 600, 800, 1,000, and 1,200 metres, each gun was to fire as rapidly as possible for 30 seconds, changing the range each fire, from the 600 up to the 1,200 metre target and back. During this test the Nordenfelt is said to have discharged 15 shot in the 30 seconds, and to have made 9 hits, while the Hotchkiss scored but 2 hits and only discharged 11 rounds in 32 seconds. Here again the elemet of inaccurate sighting may be largely responsible for the difference in the number of hits, but the great disparity in the number of rounds fired must be due to the mechanical defects in the Hotchkiss system by which the action of its breech block is too slow. Notwithstanding the reported success of the Nordenfelt gun in the the trials, the Russian Government ordered a number of Hotchkiss guns and no Nordenfelts.

ARMSTRONG 30-POUNDER RAPID-FIRE GUN.

This gun has been constructed to extend the usefulness of the rapid-fire system, which in the lighter calibres of 3, 6, and 9 pounders have shown such superiority over the ordinary breech-loading guns of light calibre. The new and larger calibres will not only be effective against torpedo.boats but will form excellent batteries for small gun boats and light vessels of all classes. The Armstrong Company have now under design a 70-pounder rapid-fire gun.

The system employed for closing the breech in the heavier guns differs widely from any of the systems used in other guns of the same class.

The ordinary screw plug with double interrupted thread is used. This plug is coned, to facilitate opening and closing the breech, and there is no hammer or firing-pin, the ignition of the charge being accomplished by means of an electric primer, and only after the perfect closure of the breech.

The general dimensions of the 30-pounder are as follows:

Length	inches	170.5
Length of bore	calibres	35.
Weight of gun	pounds	3,808
Calibre	inches	4.724
Weight of projectile	pounds	30
Weight of powder	do	9
Muzzle velocity	f. s.	1,900
Penetration in iron at muzzle	inches	6.9

One pattern of mounting for this gun consists of a slide carried on four rollers or trucks and moving around a central pivot. On the front of the slide is fixed the shield. Training and elevating are accomplished by gearing. Both hand wheels are on the left side of the gun slide and close to the shoulder-piece, so that the gunner has ready means of pointing. The top-carriage travels on the slide, the recoil being checked by a Vavasseur hydraulic cylinder. Running out is performed automatically.

The 30-pounder has been tried at the Government proving-grounds, and has been fired by a crew of 3 men at the rate of 8 to 10 rounds per minute.

The latest pattern of mount for the 30-pounder embodies the "rocking-slide" arrangement described below; but in this case the recoil cylinder is placed beneath the gun and both move together. The shoulder-piece, tramway, and elevating gear are arranged as described above. A steel ammunition box, holding eight rounds, is placed on each side of the gun and moves with it.

THE ELSWICK AUTOMATIC ROCKING-SLIDE RECOIL MOUNT FOR 3-POUNDER HOTCHKISS R. F. G.

The gun is supported on a rocking slide which pivots on transverse bearings, so that the gun moves only backward and forward on the slide.

The elevation and depression are given the gun by means of a shoulder-piece attached to the slide. There is also a clamping arc attached to the side of the slide so as to fix the piece at any desired elevation.

In front of the trunnion bearings are secured two piston-rods, that pass through stuffing-boxes into recoil cylinders, which are parts of the revolving bracket.

The interior of the recoil cylinders is slightly conical, so that a free passage of water is permitted at the beginning of the recoil and is gradually diminished as the gun runs in. At the rear of the trunnion bearings are two heavy springs, contained in boxes, which are also a part of the rocking-slide. These springs are compressed during recoil, and by the work stored in them during recoil the gun is returned to the firing position.

The trunnions of the rocking-slide rest on brackets, which are carried on a plate revolving on a central pivot. This pivot takes the weight of the mount and reduces friction when training.

The gun-shield is attached to the brackets.

The shoulder-piece is attached to the slide, and by it the gun is elevated and trained.

As the gun has a motion backward and forward a guard is fitted on the pistol-grip to prevent the trigger being pressed by the finger (as is the case in the non-recoil mounts), a firing lanyard being attached and led through a brass guard in rear. A knot in the lanyard makes it impossible to fire the gun until it has returned to firing position. The 3-pounder Hotchkiss on this mount has been fired twenty times in a minute.

84 MILLIMETRE KRUPP RAPID-FIRE GUN.

This piece has lately been built for use on shipboard and for trial on the proving-ground at Meppen. The general dimensions are as follows:

Calibre (84 millimetre)	inches	3.307
Weight	pounds	1,001
Length of gun (27 calibres)	inches	90.6
Length of bore (25 calibres)	do.	82.5
Length between sights	do.	39.4

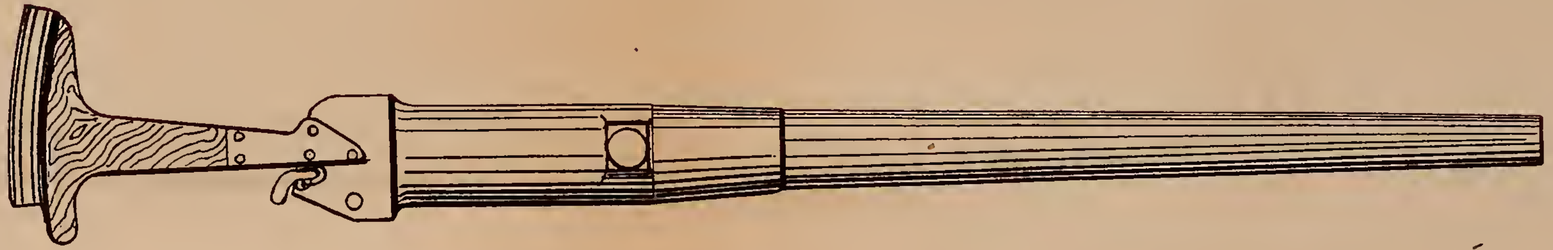
The general construction is the same as that of the 84 millimetre Krupp field gun, with the exception of the rapid-fire attachment.

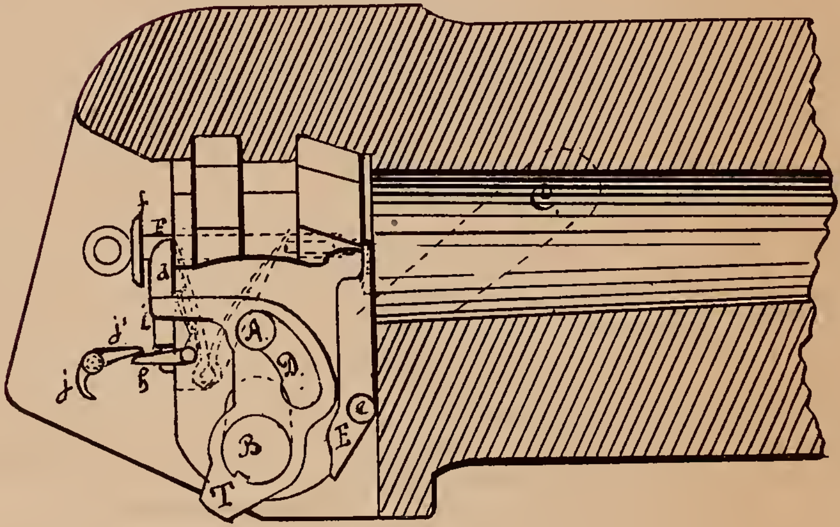
The breech mechanism consists in a block moving vertically in a slot in the breech, motion being given to it by a lever worked by a handle similar to that of the Hotchkiss guns. As the breech-block falls the firing hammer is thrown back by means of a spring; at the same time the plug in descending presses against the short arm of a bell lever, the upper end of which ejects the cartridge just as the block has reached the end of its downward motion. Like other guns of this kind there is a shield for deflecting the old cartridge case clear of the gunners.

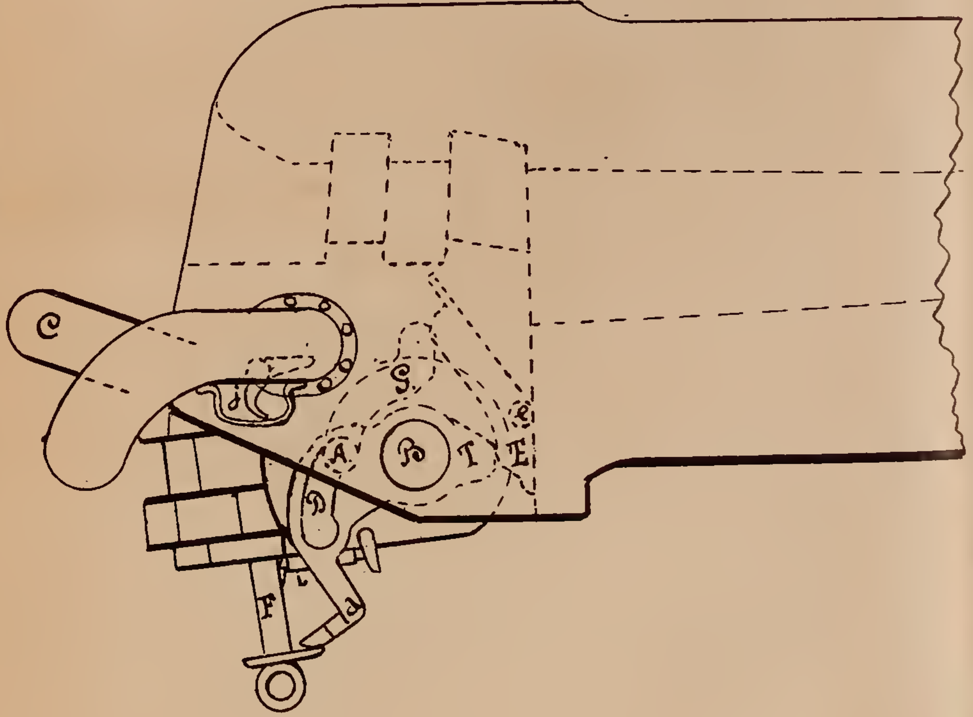
There are three kinds of ammunition provided for use with this piece, viz. shell, shrapnel, and case shot, each of which weighs 7 kilogs. (15.4 pounds).

The mount consists of a top carriage on a circular plate, which pivots at its centre on a fixed plate. The brackets of the carriage are movable about a horizontal axis on the upper disk. To the front of the movable plate is also attached a shield to

Driggs-Schroeder R.F. Gun.







which are fastened the pistons of two hydraulic recoil checks, allowing a recoil of 7.87 inches. Both the lateral and vertical train are accomplished by gearing. A seat which moves with the gun is provided for the gunner.

The full charge is 3.3 pounds, which gives an initial velocity of 464 metres (1,522f. s.).

It is estimated that three men can work the gun efficiently: One to train and fire (this man sits on the seat to the rear and side, having the lock-string attached to his waist belt so that he fires by moving his body backward), another to open and close the breech, while the third supplies ammunition.

Thus far the gun has fired 225 rounds, 55 of which were with full charges, and has worked well. In the ammunition used on trial the powder and shell were separated. In future trials the ordinary rapid-fire ammunition will be used. With the powder and shell separated it took from 7½ to 13 seconds to fire each shot; this was partly due to delays occasioned by waiting for the smoke to clear away from the muzzle.

THE DRIGGS-SCHROEDER RAPID-FIRE GUN.

In the Driggs-Schröeder gun (see plate opposite), the breech is closed by a single block, on the upper convex surface of which are projecting bands which fit in corresponding grooves in the upper interior wall of the gun, thus taking the recoil effort. A projecting guide-stud, *A*, in the side of the block, engages in a cam, *D*, which is rigidly attached to the bolt *B*, and which, with it, is operated by the handle *C*, on the left side of the gun; the pin also takes in a cam-groove, *G*, in the breech-wall, which thus directs and limits the motion of the block. In opening the breech the motion of the block, caused by turning the handle and cam to the rear, is downward bodily; then, as the pin follows the groove *G*, the motion is rotary to the rear, leaving the prolongation of the bore open. As the cam is turned a rearwardly extending arm, *d*, taking on a shoulder, *f*, on the firing-pin *F*, pushes it backward against the action of the main V-spring, until a small shoulder on the under side passes a sliding leaf, *i*, which is then pushed up by the action of a sear spring and holds it so, cocked. Also, as the cam is turned to the rear, its tail part *T* takes against the lower short arm of the extractor *E*, and gives it a pivoting motion around *e*, which motion is slow and powerful at first, and afterwards rapid, flinging the cartridge out to the rear. There are two extractors, one on each side.

The gun being reloaded, the handle *C* is turned to the front, revolving the cam and the block and closing the breech, the last part of the movement being upward; this leaves the firing-pin retracted, held by the sliding leaf. For firing, there is a trigger, *j*, under the pistol-grip on the right side of the gun, on the end of a shaft through the breech-wall; on the other end of this shaft, within the breech opening there is a finger or lip, *j'*, which presses a corresponding one, *h*, on a small shaft which actuates the sliding leaf *I* against the tension of the sear spring; the trigger, therefore, on being pressed draws down the sliding leaf and liberates the firing-pin. Normally the firing-pin rests with its point within the front surface of the breech-block, but in springing forward it is carried by its momentum beyond that position and strikes the cartridge-primer; in so doing it slightly contracts the V-spring which immediately draws it back until the point is within the front surface of the block.

The salient features of the system may be summed up as follows: The breech has no opening through the top, so that sand, dust, rain, &c., can only enter from underneath; the movable block is very light, and as it revolves about an axis within itself the weight to be handled is still further reduced: the piece cannot be prematurely fired, as until the block is up in place the rear arm of the cam would catch the shoulder on the rear end of the firing-pin and prevent the point touching the primer; the cartridge need not be pushed close home against the extractors, as the revolving block does that automatically; the two extractors grasping the cartridge case on opposite sides give it a straight, square motion, and, should the head be weak or separated on one side, the other extractor would eject it; all parts are within the breech and protected from fire, except the operating handle and the trigger, and should the latter be shot away the piece can be fired almost as readily by pressing with the finger on the lip *h* within the breech, that lip being easily and safely accessible for the purpose.

All the movements have recently been tried in a full-size working model and found satisfactory, it being loaded and fired with a dummy cartridge 32 times in a minute.

A service 3-pounder (47 millimetre) is now being built by the William Cramp & Sons' Ship and Engine Building Company, Philadelphia, which firm is assembling a complete gun plant in its works and will immediately establish a gun department. When finished, the gun will be tested at the United States Naval Proving Ground, Annapolis, Md. The system if successful will be applied to much heavier calibres, the advantage of lightness of breech-block being more and more accentuated as the size of the gun increases.

REVOLVING CANNON.

The effect of the fire of revolving cannon and small arms upon the unprotected parts of war ships was very clearly demonstrated by a series of experiments which took place in France last summer.

The old armor-clad Provence was anchored just outside the harbor of Toulon. Sixty dummies, representing that number of the crew of the vessel, were placed in different parts of the ship in the positions which they would assume in action.

Three were placed in each top, 10 on the top gallant forcastle and near the rail, 4 near the conning station of the commanding officer, 26 near the gun ports, so arranged as to represent a gun's crew, and the remainder on the forward bridge.

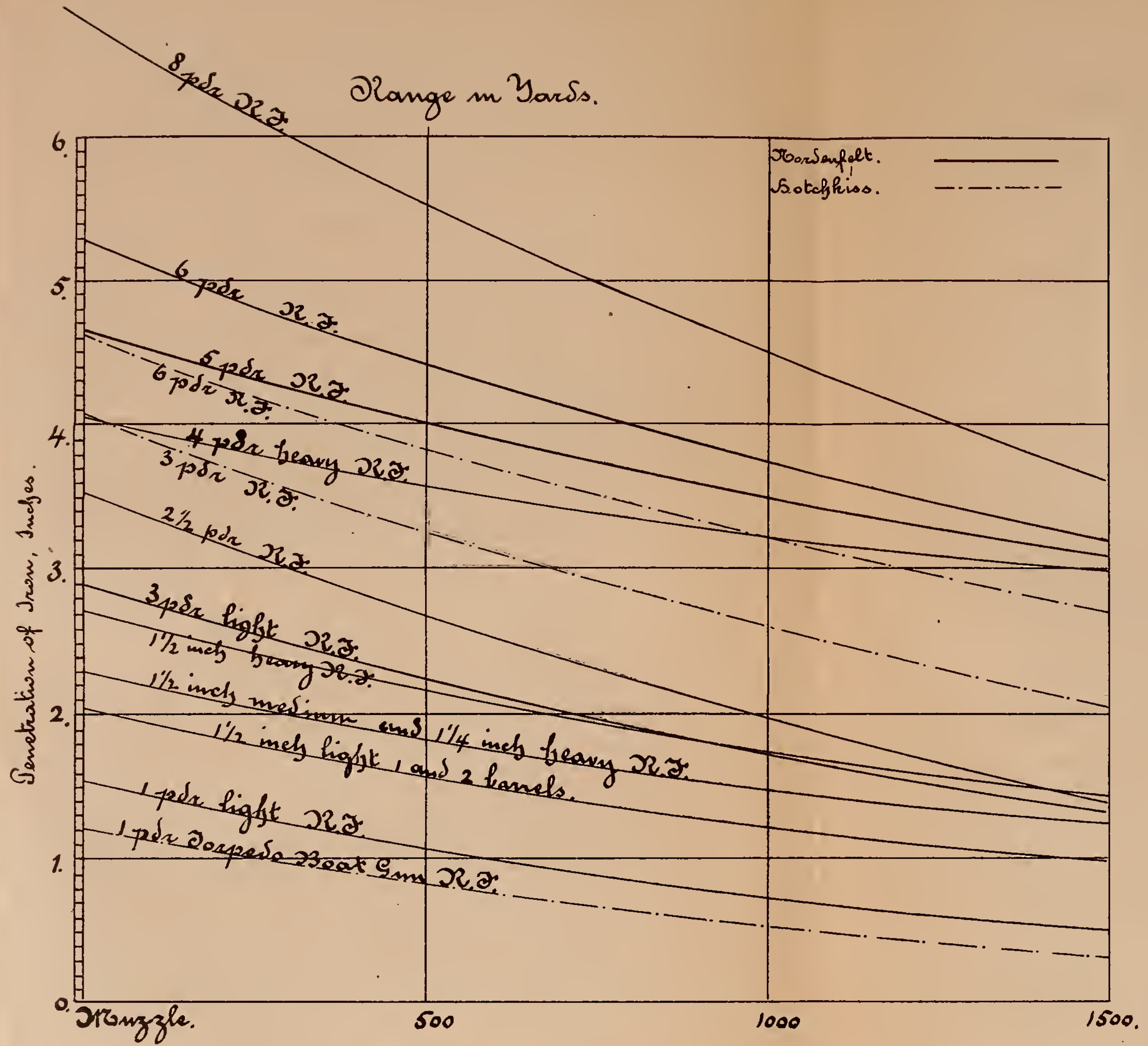
The ships selected to make the attack were the Colbert, Duperré and Dévastation. The trials were divided into three parts. The first part of the attack was so conducted that the three iron-clads should pass the Provence at a distance of about 2,000 yards, the course being parallel to her length. The firing began at a range 1,969 yards and continued while passing and within that distance. The Hotchkiss revolving cannon were the only guns used in this part of the trial. The fire continued five minutes. The three ships were now joined by the Redoutable, which took station at the end of the column. This time the fire was opened at a range of 500 metres (546 yards) by the musketry and revolving cannon directed upon the armored tops.

The third and last part of the programme was executed by the Redoutable alone, which vessel imitated the manœuvre of ramming. By signal she turned from her position at the end of the line and steamed directly for the Provence, opening fire at the same time from the forcastle and the top with her revolving cannon, and continued to fire as rapidly as possible until she had reached a distance of 200 metres, when she turned and ceased firing.

On boarding the frigate it was found that it had sustained considerable damage, so much in fact that officers and men (in positions occupied by dummies on upper deck) would have been killed, or at least put out of action, while sufficient hits were found on the dummies around the ports to show that the guns' crews on the covered deck would have suffered greatly from the attack. These results but emphasize those of the engagement in the Min River, where the revolving cannon of the French were directed with such deadly effect upon the decks of the Chinese vessels.

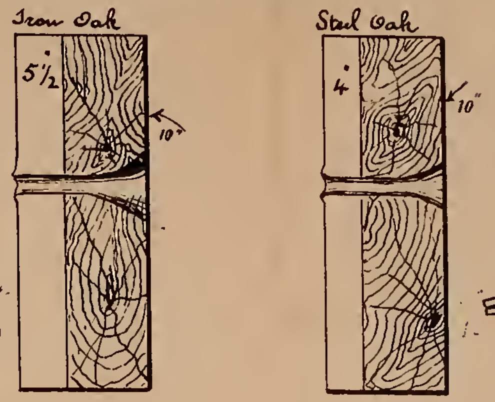
W. H. DRIGGS,
Lieutenant, U. S. N.

Penetration from Secondary Batteries.

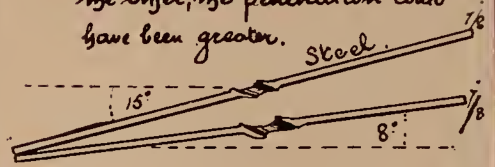


Results of trials at Spezia in 1886.

Penetration of Nordenfelt & Hotchkiss 6 pdr R.F. Guns. Range 100 yds. M.V. for Nordenfelt 2130 f.s; Hotchkiss 1805 f.s.

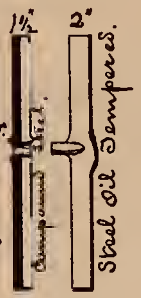


Note: As the M.V. for Nordenfelt's gun was 335 f.s. greater than the other, the penetration could have been greater.

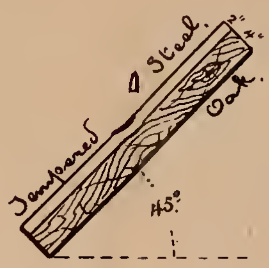


Results of trials at Annapolis, 1885 & 6.

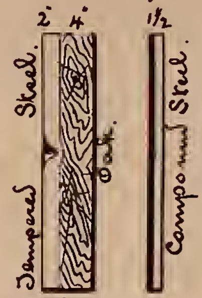
Effect of the fire of the 3 pdr Hotchkiss R.F. Range 70 ft. M.V. 1708 f.s. Steel projectile 3.3 lbs



1st Target

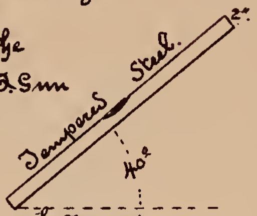


2d Target.



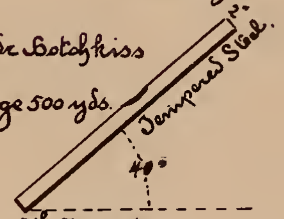
3d Target.

Effect of the fire of the 6 pdr Hotchkiss R.F. Gun Range 24 yards. 2 A.P. shell 6 lbs struck same point.



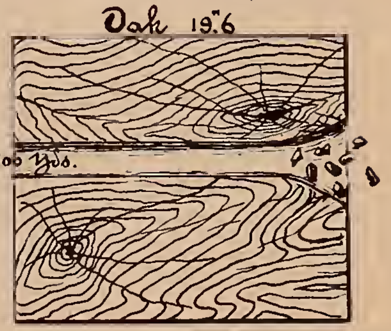
4th Target.

6 pdr Hotchkiss Range 500 yds.

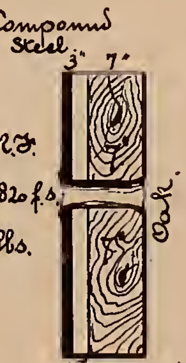


5th Target.

Penetration of 3 pdr Hotchkiss at 2800 yds.

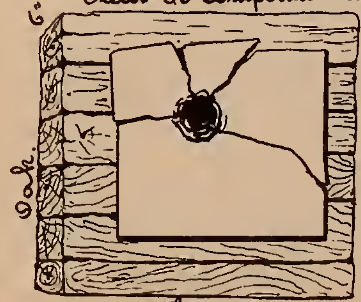


Penetration of 6 pdr Hotchkiss R.F. Striking Velocity 1820 f.s. Weight of shell 6 lbs.



6th Target.

Plate 3.5 Compound Steel.



7th Target.

6 pdr Hotchkiss R.F. Range 71 ft. Shell and Plate broke Penetration 2".

W.H. Driggs.

PROJECTILES.

ARMOR-PIERCING PROJECTILES.

Against wrought iron or the earlier and inferior grades of compound armor the chilled cast-iron shell, still in common use, was considered sufficiently good for battering purposes; but with the improvement of compound and steel armor, and with the introduction of high velocities imparted by modern high-power guns, it has been necessary to abandon cast iron as a material for battering projectiles and to endeavor to find one which is capable of withstanding the shock of impact without being broken up or deformed. The present steel battering shell has been developed chiefly in France, and has introduced another important element in the relation existing between the resistance of armor plate and the penetrating capacity of the gun.

The development of the steel projectile has but begun, and the stage thus far attained, while it gives in many cases marvelous results, cannot be regarded as altogether satisfactory. The fact is, that the experience of manufacturers of steel projectiles has hardly passed the experimental period, and the uncertainties and eccentricities occasionally encountered in steel in this form make these projectiles irregular in their performance.

Pages 235, 236, No. V, describe the methods of tempering and the trials to which steel projectiles are subjected. Similar trials have taken place abroad during the past year, and are hereafter described.

TRIAL OF HOLTZER AND KRUPP PROJECTILES IN ITALY.

A series of trials took place in Italy last year for the purpose of ascertaining the best projectile offered for trial. These experiments resulted in a competition between the Holtzer and Krupp shell. Three projectiles of each make were fired. The results are given in the following table.

Gun, 5.9 inch, Armstrong. Target, solid steel (le Creusot), 18.9 inches thick. Projectiles, empty, 79 to 81 pounds. Charge, 39.6 pounds. Velocity, 1,869 f. s. Range, 328 feet.

HOLTZER CHROME STEEL SHELL.

Number of rounds.	Penetration.	Remarks.
	Inches.	
1	9.45	Shell rebounded in each case entire, without any appreciable deformation.
2	9.37	
3	9.76	

KRUPP STEEL SHELL.

Number of rounds.	Penetration.	Remarks.
1	8.66	Shell rebounded entire; slight setting up of body, but more marked than in the Holtzer shell.
2	8.78	
3	8.89	

The results here obtained were decidedly in favor of the Holtzer shell, both as to penetration and temper.

TRIAL OF PROJECTILES AT OCHTA (RUSSIA), JUNE, 1886.

This trial was made for the purpose of testing the relative merits of the St. Chamond and Krupp steel projectiles. The conditions of the trial, together with the results, follow: Plate—Cammell, compound, 6 feet 7 inches × 6 feet 7 inches × 15½ inches. Gun, 11-inch; powder charge, 132 pounds; initial velocity, about 1,480 f. s.; fire normal.

No. of round.	Projectile.	Weight of projectile.	Penetration.	Condition of projectile.
		Pounds.	*Inches.*	
1	Krupp	548	8	Broken and smashed.
2	St. Chamond	554	15½	Intact; rebounded 30 feet.
3	Krupp	557	7–8	Broken and smashed.
4	St. Chamond	557	8–10	Broke in two pieces, transversely near the base of head.

TRIAL OF ST. CHAMOND PROJECTILE AT GÂVRE (FRANCE), 1886.

In June, 1886, a trial of 32-centimetre steel projectiles manufactured by the St. Chamond firm (France) was made at Gâvre. The projectile passed through a 12-inch le Creusot steel plate entire, and with very slight deformation. The commission reported that the trial was satisfactory, and recommended the purchase of 275 projectiles.

A lot of 27-centimetre steel battering shell, also the manufacture of St. Chamond, were tried at Gâvre on the 18th December, 1886. The shell was fired against a steel plate 25 centimetres (9.84 inches) thick, backed by 84 centimetres (33 inches) of wood, with a velocity of 455 to 465 metres (1,492 to 1,525 f. s.).

The projectile (475 pounds) passed normally through the plate and backing, and fell about 700 metres beyond the target and 100 metres to the left of the line of fire. It was then in good condition; no crack was found, but upon close examination some slight scoring was discovered. The enlargement of diameter was from 0.2 millimetres to 0.5 millimetres; the deviation of the point, 2 millimetres, and the setting-up, in length, on head, 2.8 millimetres; on cylinder, 1.2 millimetres; total, 4 millimetres. The lot was accepted.

On the 29th December, 1886, a trial of 42-centimetre steel battering shell, manufactured by the St. Chamond firm, took place. This projectile was fired against a le Creusot steel plate, 50 centimetres (19.7 inches) thick, with a velocity on impact of 430 metres (1,410 f. s.).

The projectile passed through the plate entire, and without cracks, and fell about 400 metres beyond the plate. The enlargements of diameter were found to be from 0.6 to 1.4 millimetres; the setting-up, in length, was: On head, 4.8 millimetres; on cylinder, 1.2 millimetres; total, 6 millimetres.

Shell from four prominent firms were tested at Gâvre in December last and the results may be taken as a fair illustration of the relative merits of the steel projectiles now in use. The target used for these trials was an iron plate 19.69 inches thick, placed at an angle of 20° to the normal of the line of fire. The following table contains the results of the firing, and is arranged according to the order of merit of the shell tested, as determined by the committee conducting the experiments:

[Each maker presented four shell for trial, all piercing the plate.]

	Name of maker.			
	Holtzer (no cracks in shell).	St. Chamond (no cracks in shell).	Firminy (no cracks in shell).	St. Etienne (5 small cracks, not deep).
Dimensions of hole in plate	25″. 2 × 17″. 84	23″.62 × 19″. 69	20″.08 × 18″. 51	24″. 21 × 19″. 69
Total compression of projectiles	0″. 35	0″. 24	0″. 28	0″. 79
Compression of head of projectile	0″. 35	0″. 189	0″. 24	0″. 71
Increase in diameter:				
Head	0″. 51	0″. 024	0″. 063	0″. 205
Cylinder	0″. 71	0″. 55	0″. 146	0″. 177
Deviation of the point of the shell from axis	0″. 020	0″. 059	0″. 059	0″. 375

Weight of projectile	lbs.	1,716
Weight of powder	do.	396
Calibre of gun	inches.	16. 54
Velocity necessary to perforate target	foot-seconds.	1,345
Actual measured velocity	do.	1,410. 5
Range	feet.	406

The French artillerists decided that the oblique fire of 20° against the iron plate represented the equivalent of a normal fire against a solid steel Creusot plate of the same thickness.

STEEL PROJECTILES FOR THE ENGLISH NAVY.

The English estimates for last year contained an item of £20,000 for steel shell. The admiralty consequently ordered four hundred Firminy projectiles from the agent of that firm, as they were at that time considered by the admiralty superior to all other shell. This conclusion seems to have been reached from the results of two trials, made in England in June and August, 1886. The first consisted in firing a 10-inch Firminy shell against a plate of the Conqueror type (12-inch compound), and the second in firing a 12-inch shell of the same make against an 18-inch compound plate. No details of these trials are at hand, but as the admiralty have given the order for four hundred shell to Firth & Sons, who are the manufacturers in England of the Firminy shell, the results must have been satisfactory.

Besides the four hundred Firminy shell ordered by the English admiralty, two hundred Holtzer shell ordered by the ordnance committee have been delivered. From late trials these projectiles have shown themselves to be of superior quality. In one trial in England, however, the Holtzer shell tried were not properly tempered and failed to produce the results obtained from the Firminy shell.

The Holtzer shell tried in England in March last gave very satisfactory results. The 12-inch shell perforated a 16-inch Brown compound plate and were practically uninjured. The plates were considered exceedingly good and hard.

The Firminy shell ordered by the admiralty in October last, and manufactured by Firth & Sons, have not proved as satisfactory on trial. Engineering, of May 6, contains the following:

"On reception at Shoeburyness, of the two hundred 12-inch Firminy shells three were selected for trial—one of the hardest, one of the softest, and one of medium temper. The first (weighing 718 pounds) was fired with a range of 180 yards and a striking velocity of 1,850 feet against a 16-inch Cammell compound plate 5 feet square, placed in front of 12 feet of timber backing. The shell went through the plate and 7 or 8 feet of the backing; then deflecting, it buried itself in the ground. The second projectile of softer steel, and weighing 720 pounds, was then fired with a striking velocity of 1,854 feet against a 16-inch Brown compound plate, backed with 12 feet of timber and an old target. This shot, on entering the plate, spread out, and the rear part nearly broke away from the head; four large pieces broke away and fell at the foot of the target. On measuring it was found that the shell had upset to a diameter of 14.4 inches."

The competition in steel projectiles is very active, both on the Continent and in England, and they are now recognized as necessary and indispensable for use against modern armor.

HIGH EXPLOSIVE PROJECTILES.

Another great development in the efficiency of gun-fire is found in the progress recently made in firing with safety projectiles loaded with one of the higher explosives, such as dynamite, nitro-gelatine, melenite, gun-cotton, and the like.

In this country shell loaded with dynamite have been fired from the Zalinski pneumatic gun, and on Graydon's system from the ordinary 4½-inch Army siege gun. The fire from the pneumatic gun is curved, while with that from the Army gun the trajectory is comparatively flat.

In France elaborate experiments have been made with shells loaded with melenite and fired against fortifications and vessels. But little is as yet known of the results obtained. The experiments made at Belfort came to an unfortunate conclusion by the unexpected explosion of a number of shell, which killed several people. It has been stated that this accident was occasioned by some chemical action set up by the presence of a residuum of the preparation with which the shell had been cleaned, and was not due to any want of stability in the explosive itself. Since this accident occurred (April) other experiments have been made under naval direction to test the efficiency of melenite shell against the Belliqueuse, an old wooden armored vessel.

Graydon dynamite shell.—In August, 1886, a trial of this shell took place at the Presidio, San Francisco, before a board of U. S. Army officers appointed by the commanding general to investigate and report upon this invention.

The inventor claims to be able to throw shell filled with commercial dynamite from guns now in use, with the same velocity as that given to common shell. How well this claim is sustained will appear from the following extracts from the official report: Fifty-two shell, filled with commercial dynamite, were fired with the service charge of powder from the 4.5-inch siege gun.

"With the exception of two (the results of which were lost on account of the fog) *every* shell that struck the bank or cliff fired at (range 2,200 yards) exploded by concussion, no fuze being necessary for the explosion." The board was unanimous in the opinion that the claim of the inventor had been fully proven, and recommended that the trials be continued with an 8-inch converted rifle and a 15-inch smooth-bore gun. The necessary authority to continue the trials with the guns mentioned was not given, though authority was granted to proceed with the tests, using a 100-pounder (6.4-inch) Parrott rifle and a 7-inch Ames rifle. As the proposal to continue the trials at the expense of the Government was declined, they were brought to a close.

The inventor then went to Russia, where four of his shells were fired from a 6-inch rifle with a charge of dynamite mixed with powder. For comparison four other shell were discharged from the same gun, using powder both in the shell and as a firing charge. The results are very clearly set forth in the following letter and table, which have been presented as copies of official communications:

ARTILLERY DEPARTMENT,
St. Petersburg, Russia, January 4, 1887.

Lieut. JAMES WEIR GRAYDON,
Late U. S. Navy, Hotel de France, St. Petersburg, Russia:

SIR: I have the honor to forward you the table of pressures, velocities, &c., of the four shots of yours with the 6-inch rifle with dynamite and powder in charge, and dynamite in shell, as compared with our four shots with powder only. You will see that you increased the velocity per second 494 feet, and I am directed by the president of the special committee, the Lieut. General Notbeck, to inform you that the committee are of the opinion that such increase of velocity is very satisfactory, and even more than you promised.

Respectfully, &c.,

MAJOR-GENERAL SNESSEROFF,
Steward of the Ordnance Committee, &c.

Translation by Lieutenant Younger, Member of Special Committee, and Recorder.

[Date of firing: December 29, 1886.]

Number of round.	Nature of projectile.	Nature of charge, in pounds.		Velocity of each of the four shots made for comparison.	Average.	Pressures in bore by Rodman gauge.			
						No. 1, atmospheres per square inch.	Average per square inch.	No. 2, atmospheres per square inch.	Average per square inch.
		Powder.	*Dynamite.*	*F. s.*	*F. s.*				
1	Cast iron, filled with dynamite, total weight, 102 pounds.	37	1	1987	1993	1721	1736	1725	1735
2	......do..............	37	1	1991		1742		1740	
3	......do..............	37	1	1998		1739		1736	
4	......do..............	37	1	1996		1745		1741	
		Powder only.							
1	Cast iron, filled with powder, total weight, 102 pounds.	38		1502	1499	1703	1721	1711	1724
2	......do..............	38		1497		1727		1721	
3	......do..............	38		1489		1731		1741	
4	......do..............	38		1511		1726		1723	

These results are remarkable, and are published as given, although this Office cannot vouch for the accuracy of the table.

ARMOR.

During the last year no further competitive trials have taken place to settle the still much discussed question of superiority of all-steel and compound armor plates, nor has either party engaged in the manufacture of these yielded any of its convictions. There has been evidence, however, of a decided gain to the list of adherents of the all-steel system. It has been reported by at least one prominent London technical journal that the British officials have had their confidence in the power of compound plates to withstand the shock of steel projectiles considerably shaken, and have so seriously considered the question of a change to the all-steel plate as to invite the study of the English compound-armor manufacturers to this subject. Italy continues to armor its vessels with steel plates; Spain has adopted and accepted the Creusot plate for its new formidable armored vessel, the Pelayo; and China, too, has recently become a purchaser of Creusot plates.

But the most important addition to the list of nations favoring the use of steel armor is that of the United States. In August, 1886, the Navy Department, in a circular to the steel manufacturers of this country, declared for steel armor and invited proposals for some 6,700 tons of plates of varying thicknesses (2 to 13 inches), shapes, and dimensions. This decision was arrived at after several years of investigation and study on the part of the Navy Department, and was in accordance with the opinions expressed by the Gun Foundry Board in 1884, the Coast Fortification Board in 1885, and the select committee of the Senate of which Senator Hawley was chairman. These opinions were reached by members of these boards and committee after personal investigation at home and abroad, and doubtless reflected the unprejudiced advice of the most distinguished metallurgists of the world.

The result of the invitation for bids was obtained on the 22d March, and the contract for furnishing the steel armor plates for the monitors and new armored vessels has been awarded to the Bethlehem Iron Company The nation as well as the naval service is to be congratulated upon this outcome, which assures a domestic supply ot armor, which, if up to the accepted requirements and conditions, will be unsurpassed by any in the world, and at once makes the country independent of foreign markets for much needed armor. It is most fortunate that this contract has been secured by a company acknowledged to be one whose financial condition is most sound and whose administration is most able.

The terms of the contract provide that the company must establish its plant within two and a half years, and that all the plates must be delivered within two years after that time. It is probable, however, that the armor plant will be in working order before the end of 1888. The plant will doubtless be of the most approved pattern, including hammers and forging presses of the highest power, and, as indicated by Mr. Sayre's letter, arrangements have already been made for its installation.

Office of the Bethlehem Iron Company,
Bethlehem, Pa., March 18, 1887.

Hon. William C. Whitney,
Secretary of the Navy, Washington, D. C.:

Dear Sir: Referring to the circular issued by the Navy Department under date of August 26, 1886, I find this provision: "Nor will any bid be accepted unless accompanied by evidence satisfactory to the Department that the bidder is in possession of, or has made actual provision for, a plant adequate for its fulfillment." This seems to require the following summary statement to be made:

First. The Bethlehem Iron Company has been most diligently engaged for more than a year in constructing a complete plant of forging machinery and tools adapted to the fabrication of all the parts of the largest guns used in any part of the world, and of the shafts that may be required for vessels of any size that the United States Government may require, and in erecting the necessary buildings in which to do this work. The establishment when completed will be in every respect fully able to compete with any establishment in Europe.

Second. It has contracted with one of the largest and most successful concerns in Europe engaged in making steel armor plates for the necessary aid, superintendence, use of patents and guarantee of its work, and has arranged for a hammer of the largest class if that be deemed necessary to the successful prosecution and completion of the work required by the Government.

Third. The company has, up to this time, expended in cash on the forging plant alone between $300,000 and $400,000, and is under contract obligations to the extent of $500,000 additional for machinery and tools, to be delivered within the current year. The amount required to complete the plant for both guns and armor-plate will be in all about $1,500,000, and for this the financial arrangements are completed.

Fourth. The company has now in operation seven blast furnaces. It owns or controls large deposits of ore peculiarly suitable for such iron as is needed for steel forgings, so that it is certain of obtaining the best and most uniform quality of metal without being subject to the difficulty and uncertainty of purchasing in the market suitable material.

Fifth. In addition to what is being done in the way of special preparation for this heavy class of work the Bethlehem Iron Company now has in use, in connection with its present work, a large machine-shop thoroughly equipped with the largest and most effective tools in this country, a foundry, smith shop and other necessary appendages, and is now turning out about 4,500 tons of steel per week.

Sixth. The Bethlehem Iron Company has, what is quite as essential as any other item to insure satisfactory results, a large corps of trained, skilled experts, mechanics, and workmen, commanded by a chief of well-known and acknowledged ability, accustomed to accomplish what he undertakes. It has also made adequate arrangements for procuring all the needful assistance of men trained to the special work now called for by the Department.

Very respectfully,

ROBERT H. SAYRE,
General Manager.

The question of cost, which has been a very uncertain factor, has been satisfactorily settled. The following table indicates the cost of armor at home and abroad:

	Bethlehem.	Le Creusot abroad.*	English compound abroad.*	Miantonomoh's armor (English) delivered at New York navy-yard.
Average price of armor plates alone..per ton..	$536 16	$380 to $400	$430	....
Average price of armor bolts........ " ..	650 00	580 to 600	375	....
Average for lot .... " ..	538 70	....	....	$535

* About.

The satisfactory terms of the contract upon which the Government has entered are at once apparent. Not only is the price moderate, but the plates must equal, if not exceed, in endurance that demanded of similar plates abroad.

The following extracts from the circular of the Navy Department, containing the specifications for armor, indicate the requirements of material, manufacture, and tests:

STEEL ARMOR PLATES FOR U. S. NAVY.

The vessels that it is proposed to supply with armor are the following:

Monitors.	Displacement.	Approximate weight of armor.
	Tons.	*Tons.*
Puritan	6,060	1,053
Amphitrite	4,000	618
Monadnock	4,000	613
Terror	4,000	618

And two other vessels of about 6,000 tons displacement each.

The designs of the other two vessels are still unsettled, and will probably not be the same for both ships. It seems probable, however, that they will not differ very much in the area and number of their plates, though one may carry thicker armor than the other.

As the exact way in which they will be protected is not known, an opinion as to the character of the plates required can only be formed by considering that they will carry heavy batteries (with the necessary machinery, coal, and stores), and be as heavily armored as their displacement will allow.

It is probable that the total weight of steel armor and accessories required for *all* the vessels herein referred to will not be less than 6,690 tons.

As the object of the contract will be the production of first-class armor plate, the contractor must furnish and maintain the most improved modern plant for such work, which must be conducted according to the best methods. He is to use every endeavor and incur all the expense necessary to produce the most resisting and enduring plates, and he is to regard the tests herein set forth merely as minimum limits of quality which he is bound to excel, as much as practicable, by the use of all the means which should be within the reach of a first-class establishment.

Armor plates for each ship will be divided into lots, as the Department may determine.

Before manufacture commences the contractor will be informed what plates compose each lot.

The plates must be of the best quality of material, free from imperfections of manufacture, and from such cracks, cavities, flaws, slag, sand spots, cinder, blow holes, seams, and other defects as would diminish their resistance or value. They must all possess an effective ballistic resistance.

They shall be of the best workmanship, with such careful planing and finishing as may be required; and are to be completed (within the tolerances given below) to the sizes and shapes shown on the drawings which will be furnished to the contractor, or otherwise plainly designated by the Department. Their edges must be sharp, properly inclined, and finished as per drawings, and they must fit properly upon the vessels for which intended and against contiguous plates and structures.

Where special nicety is required by the construction of the vessels, they shall fit smoothly and closely.

The exterior and interior faces will be finished by the forge or rolls, but they must be smooth and free from great or extended irregularities.

Maximum variations that will be allowed in dimensions of plates:

In length: less 0.2 inch, more 0.

In width: less 0.2 inch, more 0.

In thickness: less 0.08 inch, more 0.08 inch.

In the versed sine of curves a variation of 0.08 inch more or less will be allowed per yard of chord, but not in any case to exceed 0.2 inch.

The bolt holes in the plates are to be made and threaded of dimensions, in numbers and in the directions shown on drawings to be furnished the contractor, or as stated by the Department (usually normal to the inner surface of the plate at the center of the hole). The bolt holes are tapped into rear surface of the plate, and do not go through.

MANUFACTURE AND SELECTION.

All raw material shall be chemically analysed in the most approved manner, by the contractor, before use, and proper records thereof, and proper melting records, shall be kept by him.

Whatever method may be adopted for producing ingots, the part of each which is to be used in making the untrimmed plate must be equal in quality and in all other respects to an ingot cast in the usual way, from which, at least, 30 per cent. by weight has been discarded from the upper end, and 3 per cent. from the lower end.

At least two chemical analyses shall be made, by and at the expense of contractor, from each ingot (one from each end), and records thereof shall be kept by him.

Ingots must be free from imperfections that would injuriously affect the finished plate.

From the discarded pieces, and at points as near as practicable to the portion of the ingot from which the plate is to be made, shall be taken four test-bars, two from each end, each of which will be reduced, by forging, until the ratio between its original and final forged cross-section equals 2¾.

The specimens turned from these bars must be cylindrical in form, between measuring points, which will be 2 inches apart, and the diameter of the cylinder will be one-half inch. They may be annealed, but not tempered, and when physically tested they must not show a less mean tensile strength on the original cross-section than 82,000 pounds per square inch, nor a less mean final elongation than 20 per cent. The variations from the mean must not be large.

The ingots will be graded by the inspector into "groups" for the ballistic test, the members of each group must be nearly alike in quality, especially in physical characteristics.

The "group" must not be confounded with the "lot"; the latter term applies to a certain number of neighboring plates on a ship, while the "ballistic group" *may* be composed of plates belonging to widely different parts of the vessel, though, of course, a most desirable result will be attained when the "lot" and the "group" are identical, and every effort must be made to effect this.

After the ends of an ingot are discarded (as above) its weight must be at least 34 per cent. in excess of that of the trimmed and finished plate. The ingot shall be forged or rolled as much as the best practice requires, but in no case shall the ratio between the mean cross-section of the ingot and that of the trimmed and finished plate be less than three. During the process of reduction, as above, no metal shall be cut off except such as will clearly have no further beneficial effect on the working of the metal which is to compose the finished plate.

All the members of a group shall receive a practically uniform treatment.

After the plates have been subjected to all the treatment they are to receive, and are otherwise entirely finished (except bolt holes), tests will be made from them for the purpose of exhibiting both absolute and relative quality, first in those parts of the same plate which have received similar treatment, and second between all the plates of a group. For this purpose, four specimens will be taken from the bolt-holes in the rear face of each plate.

BALLISTIC TESTS.

The ballistic test is the chief one, and the object of all the other tests of ingots and plates is to insure, so far as possible, that the remaining plates of a group are capable of standing as severe a test as that to which the test plate has been subjected, and the conformity required among the plates of a group will be only such as may be necessary for this purpose. The plate from each group intended for the ballistic test will be selected by the Department at any stage of the manufacture, after the group that includes it is forged, cut virtually to dimensions, shaped and completely treated. It will be prepared for test at the expense of the contractor. The ends must be trued.

The bolt holes will be arranged when conveniently practicable in the same manner as for fastening the plate to the vessel's side.

After the test plate is received at destination the Department will proceed to the tests as soon as practicable, and work on the group may be suspended (if the contractor so desires) until the result of the test is announced.

The ballistic test will be at the expense of the Department.

The plate will be bolted against a substantial wooden backing 36 inches thick. If the plate is tapered or otherwise intentionally varied in thickness, the backing will be maintained of full depth behind the thinnest part, and will be faced off behind the other parts in such a way as to bring the front face of the plate vertical. The whole structure will be braced from the rear, and the bolts will be of the same kind as are to be used on shipboard.

Near the middle region of the plate there will be marked three points of proposed impact, arranged so as to form an equilateral triangle, each side being in length three and one-half times the diameter of the shot to be used in the test. If at any time the contractor desires to shorten a side or sides of the triangle it will be done.

For plates of constant thickness one apex of the triangle will be placed upwards, the other two being disposed below on a horizontal line.

For plates tapering in thickness, two of the proposed points of impact will be arranged in the thinner part, on a line parallel to that upon which the taper commences, and when practicable, at least one calibre from it. The third point will be placed on the thicker part.

If the distance from any apex of the triangle (as laid out) to the edge of the plate is less than 1½ calibres of the projectile, the Department may arrange the proposed points of impact in a straight line, near the middle line of the plate, and preferably in its thin part; the space between the proposed points of impact must remain at 3½ calibres. In such circumstances the centre shot shall be delivered last.

The rules regarding positions of the points of proposed impact are intended as aids to conducting the test with regularity. The guns will be aimed for these points, but no allowance will be made for the ordinary errors inherent to artillery fire.

When the proposed point of impact falls upon the tapered part of the test plate, the thickness for which the velocity is to be calculated shall be measured at the thinnest point on the circumference of a circle described around the proposed point of impact, with a radius equal to the semi-diameter of the shot.

Differences of level of the surface caused by imperfections of workmanship shall not accrue to the advantage of the contractor in measuring the thickness of plates.

The velocity of the projectile will be such as gives by calculation sufficient energy to cause the projectile to just pass entirely through a wrought iron plate and its wooden backing; the wrought iron plate being supposed to be equal in thickness to the test plate, and the backing to be 36 inches thick; the latter subject to the reduction hereinbefore mentioned for plates of varying thickness.

The velocity will be calculated by the following well-known formula of Gâvre, in which the projectile is supposed not to experience any change of form while passing into or through the target. The same charge of powder being used, the actual striking velocity will vary from that obtained by calculation within the usual limits:

$$\frac{p}{a}V^2=3507\ E^2+2265464\ e^{1\cdot4}$$

p = the weight of the projectile in pounds.
a = the diameter of the projectile in inches.
V = the velocity, at impact, of the projectile, in feet per second.
E = the thickness of the backing in inches.
e = the thickness of the armor-plate in inches.

The following table shows the velocity and energy (calculated by the above formula) that would be used in firing against plates of different thickness, employing certain guns:

Target.		Gun with service shot.	Value of p.	Value of a.	Velocity at impact.	Total energy at impact.
Plate.	Backing.					
Inches.	*Inches.*		*Lbs.*	*Inches.*	*Foot-seconds.*	*Foot-tons.*
6	36	6-inch B. L. R..	100	5.96	1,389	1,337
7	36	6-inch B. L. R..	100	5.96	1,528	1,619
8	36	8 inch B. L. R..	250	7.96	1,213	2,550
9	36	8-inch B. L. R..	250	7.96	1,308	2,966
10	36	8-inch B. L. R..	250	7.96	1,399	3,390
11	36	8-inch B. L. R..	250	7.96	1,489	3,839
12	36	10-inch B. L. R..	500	9.96	1,247	5,386
13	36	10-inch B. L. R..	500	9.96	1,315	5,987
14	36	10-inch B. L. R..	500	9.96	1,381	6,608
15	36	12-inch B. L. R..	850	11.96	1,215	8,699
16	36	12-inch B. L. R..	850	11.96	1,269	9,710
17	36	12-inch B. L. R..	850	11.96	1,332	10,454
18	36	12-inch B. L. R..	850	11.96	1,374	11,124
19	36	12-inch B. L. R..	850	11.96	1,425	11,965
20	36	12-inch B. L. R..	850	11.96	1,476	12,837

A steel projectile (of the best quality and manufacture, as determined by the Department) will be fired at each of the three points of proposed impact, under the general conditions before described.

No projectile nor any fragment of the plate must get wholly through the plate and backing.

The plate must not break up and pieces be displaced, so as to expose the backing, before the impact of the third shot; neither must very large cracks which expose the backing appear before the impact of the third shot.

Firing at a plate will be stopped whenever, in the opinion of the inspector, the plate has demonstrated its incapacity to stand the full test.

If the temperature of the air, at the time of the test, is above 40° Fahrenheit, the test plates may be warmed to not above 60°, on the request of the contractor, and at his risk and expense. If the temperature is below 40° the Department will pay for the warming (if demanded), the risk remaining as before.

No plate which does not represent a ballistic group will be tested under the contract.

If, before the selection of a test plate from a ballistic group, the contractor shall offer in writing to submit it to a ballistic test corresponding to that established by the formula for a plate of 25 per cent., 35 per cent., or 45 per cent. greater thickness, it shall be so tested, and if the group passes, the other conditions of acceptance remaining as before, a premium will be allowed on the groups of $30, $50, or $100 per ton, according to the percentage of increased ballistic resistance exhibited as above.

These conditions will only apply to armor for the protection of the hull and gun stations, and to none whose maximum thickness is less than six inches.

DECK-ARMOR, GUN-SHIELDS, ETC.

All rolled armor-plates for deflective decks, light gun-shields and similar purposes will be made of the best material, and will be oil-tempered and annealed. They will be subjected to the following tests for acceptance: Two specimens will be taken from each heat of deck-armor; these must show not less than 85,000 pounds tensile strength and 20 per cent. elongation. Two specimens will be taken from each gun-shield; these must show not less than 95,000 pounds tensile strength and 15 per cent. elongation.

Plates will be delivered cut and trimmed to shape, according to drawings to be furnished.

INSPECTION.

The Department shall have the right to keep agents or inspectors at the works, who will have free access to all parts thereof, and will be permitted to examine freely the raw material, to witness all the processes of manufacture, and to examine the contractor's records with reference to such matters.

MISCELLANEOUS.

Accepted and test plates, with bolts and other objects, must be delivered F. O. B. a convenient transportation line (to be approved by the Department) that runs from the town in which the contractor's works are situated.

Turrets and other complete structures are to be erected at the works of the contractor and verified as to thickness, form, &c., before being delivered.

BOLTS, ETC.

The material to make these (bolts for about 6,500 tons of armor) will weigh in the rough about two hundred (200) tons.

They may be unfinished on the reduced part of the shaft and on the flat of the head They must be in other respects accurate in form, well made, of proper sizes, and in accordance with the drawings.

The nuts and heads can be unfinished on the upper or outer flat. They must be to size and be finished on the friction face. All threads to be carefully made and verified by the templates or patterns.

The cups will be of rolled steel plate, sound and of very mild quality.

Washers are to be of wrought iron, free from defects.

Both the bolts and nuts will be of the best quality of steel, and subjected to a double oil temper, the first at a high and the second at a low heat.

From one per cent. (1 per cent.) of the bolts, test bars will be taken longitudinally, and when tested must give the following minimum results on a specimen 2 inches between measuring points, and ½ inch in diameter:

Tensile strength per square inch of original cross-section, 64,000 pounds.

Elongation (final), 23 per cent.

Similar specimens taken in the same proportion from the nuts and in the direction of their height shall show as a minimum:

Tensile strength per square inch of original section, 78,000 pounds.

Elongation (final), 14 per cent.

These specimens can be taken from the rough forged material after it has received all the treatment to which it is to be subjected.

Wrought iron tubes will be furnished for side armor to take the shanks of the bolts through the backing.

They can be delivered rough, but must be of correct form and properly sized, and the ends finished.

The tolerance allowed will be as follows:

On the exterior diameter, 0.02 inch, less.

On the interior diameter, 0.04, inch, more.

Washers and tubes must sustain the following proof: Longitudinal test bars will be taken from one per cent. (1 per cent.) of them, and must show the following minimum results:

Tensile strength per square inch of original section, 48,000 pounds.

Elongation (final), 15 per cent.

The weight of delivered material will be determined on the scales at the contractor's works, 2,240 pounds to the ton. The Department will have the right to check these weights by reweighing. If, for completing the vessels herein mentioned, the Department should require a greater weight of armor than provided for in the exhibits, it will pay for the extra weight at the price per ton bid for the corresponding exhibit most similar to the additional plates ordered. The same rule will apply to bolts and appendages.

As it is well known that no plant, capable of manufacturing the armor plates herein called for now exists in the United States, it becomes necessary to have from the successful bidder, within fifteen days after notification that his bid has been accepted and before the execution of a contract, evidence satisfactory to the Department that actual provision has been made for securing, within two and a half years, a suitable plant adequate to the production and proper forging or rolling of the heaviest plates herein described at the rate of 300 tons of finished plates per month.

The contractor will be required to deliver all the armor and accessories necessary for the six vessels which it is proposed to armor within two years from the expiration of the contract time for the completion of an adequate plant.

WILLIAM C. WHITNEY,
Secretary of the Navy.

NAVY DEPARTMENT,
Washington, February 12, 1887.

The fact that steel plates are exclusively used at the proving-ground of Gâvre, France, for the trial of indeformable steel battering projectiles, may be taken as another indication of their superiority. It is evidently believed by the French officers, who have had much experience with both systems of armor, that the steel plates offer greater resistance to, and entail more work upon, the indeformable projectiles than do the compound plates.

The steel on steel plates (those having hard-steel faces and soft-steel backs), spoken of in last year's publication, and manufactured by the St. Chamond-Marrel Frères Works, have not turned out as desired. The great difficulty lies in welding the two qualities of steel. The study and manufacture of this type of armor has but begun; if the difficulties are overcome the hightest results should be obtained.

In the contest between gun and armor which has continued on European proving-grounds during the last twenty years, the gun has always proved the victor. At this time it is possible that heavy guns have about reached the limit of power, and in the opinion of many they have already overreached the limit of weight desirable to mount on board ship. Doubtless armor plates can be further improved and the relative efficiency of gun and armor more nearly equalized, but with this equalization of gunpower and plate-resistance there enters another element, heretofore comparatively neglected, but now receiving the greatest attention and study—the projectile. Some accounts of trials of steel projectiles will be found on page 317, and from these may be seen the enormous work which the plate must endure to keep out the newly developed missiles.

The field for increasing the power of the gun now lies chiefly in the development of the indeformable steel battering projectile, which as yet is barely passing from its experimental stage.

ARMOR TRIALS.

Steel plates (*le Creusot*) *for the Pelayo at Gâvre, October* 1, 1886; 1st lot, plate 14.7 feet × 6.8 feet × 11.7 inches upper edge, 7.9 inches lower edge. Weight of plate, 18 tons. Plate normal to line of fire.

First shot.—Gun 24 centimetres (9.45-inch) B. L. R. Projectile (chilled cast iron), 317 pounds; powder charge, 71 pounds; velocity, 1,281 foot-seconds; energy, 3,616 foot-tons; thickness of plate at point of impact (right-hand base of triangle), 9.1 inches.

Second shot.—Same gun, projectile, &c., charge, and thickness at point of impact (left-hand base of triangle); velocity, 1,278 foot-seconds; energy, 3,598 foot-tons.

Third shot.—Same gun and projectile; powder charge, 82.5 pounds; velocity, 1,395 foot-seconds; energy, 4,287 foot-tons; thickness of plate at point of impact (summit of triangle), 10.4 inches.

Fourth shot.—Same conditions as in third shot. Shot struck near upper right-hand corner.

Effects.—At the end of the trial, after the fourth shot, no portion of the plate was broken off or detached, all bolts remained intact, and the backing was uninjured. The plate was badly cracked in four directions. The projectiles broke up; the heads of the third and fourth stuck in the plate.

The lot was accepted with the remark "Satisfactory."

Second lot, January 10, 1887. Plate 16.6 feet × 6.7 feet × 17.7 inches upper edge, 12 inches lower edge. Weight of plate, 30 tons.

First shot.—Gun 27-centimetre (10.6-inch) B. L. R. Projectile (chilled cast iron), 475 pounds; powder charge, 130 pounds; velocity, 1,434 foot-seconds; energy, 6,799 foot-tons; thickness of plate at point of impact (right-hand base of triangle), 13.4 inches.

Second shot.—Same gun and projectile; powder charge, 128 pounds; velocity, 1,420 foot-seconds; energy, 6,662 foot-tons; thickness of plate at point of impact (left-hand base of triangle), 13.2 inches.

Third shot.—Same gun and projectile; powder charge, 150 pounds; velocity, 1568 foot-seconds; energy, 8,119 foot-tons; thickness of plate at point of impact (summit of triangle), 15.4 inches.

Effects.—At the end of the trial no portion of the plate was broken off or detached, all bolts remained intact, and the backing was uninjured. The plate was cracked in four directions. The projectile broke up. The heads of projectile stuck and were thrown out by the concussion of each succeeding shot.

The lot was accepted with the remark "Very satisfactory."

An examination of the photographs of these plates confirms the claim made by the manufacturers that however much the plate is punished it practically remains intact, and is still a complete protection against projectiles.

Compound plates (*Saint Chamond*) *for the Hoche, at Gâvre,* 18 *June,* 1886. Second lot, plate 17 feet × 3.5 feet × 9.8 inches upper edge, 7.9 inches lower edge. Weight of plate 10.7 tons—placed normally to line of fire.

First shot.—Gun 19-centimetre (7.5-inch), B. L. R.; projectile (chilled cast iron), 165 pounds; powder charge, 54 pounds; velocity, 1,593 foot-seconds; energy, 2,912 foot-tons; thickness at point of impact, about 8.9 inches.

Second and third shots.—Were fired under same conditions; the energies were 2,930 and 2,912 foot-tons. The shots struck on a central horizontal line, about 15 inches apart; the third struck at centre of target and between the first and second.

Fourth shot.—Struck in the hole made by third shot, with same energy, &c.

Effects.—At the end of the trial the plate showed several fine cracks. When stripped it was seen that a bad but not extensive crack extended through plate in rear of shots 1, 3, and 4, and that the joint or solder was badly broken for a distance of some two feet. The plate, however, was in remarkably good condition, and remained thoroughly efficient as a protection against similar projectiles.

This plate received in the aggregate the shock of 11,666 foot-tons, while the Pelayo plate, first lot, of nearly same thickness, withstood the shock of 15,788 foot-tons.

New Cammell plate tried at Portsmouth, England.—The English service journals of April 16 report the trial of a plate manufactured on a new patent of Mr. Wilson (Cammell & Co.). Its dimensions are 8 feet × 6 feet × 10½ inches. The face was specially hardened to withstand penetration, and in addition to the usual iron backing it was further strengthened by a third strake of soft iron, as hereafter described. Three regulation rounds were fired from the 10-inch 18-ton gun (M. L. R.), at a range of 30 feet, with a charge of 70 pounds and a chilled iron projectile of 400 pounds. The muzzle velocity was 1,364 foot-seconds, and the muzzle energy 5,288 foot-tons. The hits were distributed in the usual triangular figure, and produced no penetration, the projectiles breaking up. No damage was done the plate with the exception of bruising its face. After this regulation trial there were fired a steel forged shell, a steel cast shell, and a cast-iron shell, all of foreign manufacture. "None of the projectiles got through; the steel shells were broken up, and the cast-iron shell almost reduced to powder."

IMPROVED PROCESS OF MANUFACTURE OF THE CAMMELL (WILSON) COMPOUND PLATE.

A patent has recently been taken out by Mr. Alexander Wilson, of the firm of Cammell & Co., for the further improvement of compound armor plates.

This is effected by taking a wrought-iron fibrous plate, about 15 inches thick (for example), built up from a number of thinner plates by placing it while hot from the forging process into an iron box or mold of proper dimensions for further treatment. The depth of a mold for the plate in question would be about 28 inches. Upon one face of the wrought-iron plate is run a layer of "ingot-iron" about 13 inches thick. The plate is then taken from the mold, reheated, and subjected to a hammering or rolling process until reduced in thickness to about 18 inches. This combination forms the "iron backing" of the compound plate. It is again put in the mold, and on the exposed face of the original wrought-iron plate is run a layer of hard steel, about 8 inches thick. The plate is now, in the rough, about 26 inches thick. It is again taken from the mold, reheated, and rolled or hammered or pressed to the desired thickness—20 inches. The plate is then allowed to cool. Afterward it is planed and otherwise machined to the proper form and dimensions.

The steel face is of hard metal, contains from 1.25 to 1.50 per cent. of carbon, and offers great resistance to penetration of projectiles. The steel and ingot-iron can be produced by the Bessemer or Siemens-Martin process. The centre layer of the plate is made of the best puddled fibrous iron.

It is claimed by the inventor that the superior hardness of the steel face will break up any projectiles fired against the plate, and will resist the penetration thereof, while the back of the plate, being tough and ductile, and with great tensile strength (26 to 30 tons per square inch) is better enabled to support the front layer. The plate thus made is stratified, and it is claimed that the fractures or cracks which may be produced on the hard steel face will not extend through the plate.

Plates made under this process have been tried as indicated above.

Whatever additional efficiency may be gained by this change of manufacture must be gained at considerable additional expense, and if, as heretofore claimed, the weld of the compound system is a weakness and an obstacle to the proper working and forming of the plate, this must be doubly the case in those plates made under the new process.

TORPEDOES.

Several new patents of torpedoes have appeared during the past year. Until they have gone through the modifications liable to be introduced during actual manufacture, they may be considered as simply illustrating more or less novel applications of well-known principles. Progress has also been made in perfecting some other types of recent invention. Prominent among the latter may be mentioned the Hall and the Peck, described, respectively, on pp. 27 and 28.

Trials are about to be made by a Naval Board in the United States of torpedoes of domestic manufacture. In the instructions to the Board the following qualities are mentioned as being essential in torpedoes adapted to naval warfare:

(1) Accuracy.

(2) Certainty of operation: (*a*) Certainty of launching and starting on the course; (*b*) certainty of explosive action on contact with the target.

(3) Velocity.

(4) Range.

(5) Ability to break through or avoid hostile defensive obstructions.

(6) Destructiveness.

(7) Safety in handling.

(8) Ability to keep in readiness for immediate action.

(9) Facility of manipulation.

(10) Simplicity.

(11) Ability to be operated with safety from an enemy's fire.

(12) Simplicity and efficiency of the launching apparatus.

(13) Noiselessness.

In connection with these qualities the Board has been instructed to note the following points:

Is the torpedo difficult of manufacture, and is great accuracy of manufacture necessary in order to obtain uniform results?

Is great structural strength necessary?

What effect has the motion of the vessel at sea on the preparation of the torpedo and on the torpedo itself when in position for firing, and what effect has the motion of the vessel on facility of pointing?

Is the preparation of the torpedo for action an elaborate process, and while it is being handled and when in position for service are the vessel and her crew reasonably safe from injury?

Is much care necessary in order to keep the torpedo in a proper state for speedy use?

Is the actuating apparatus or material reasonably safe and harmless, both when loaded and when in store, and does it probably deteriorate or dangerously change with time or with the changes of temperature and other conditions incident to service?

Can the torpedo be made innocuous (automatically) at the end of the flight?

Is the torpedo adapted for "exercise" practice? Is the motive power readily supplied in sufficient quantity to allow frequent exercise? Is exercise expensive, and can the torpedo be recovered and practice with it resumed speedily?

Can the torpedo be conveniently and safely packed for transportation?

What is the probable cost to manufacture the torpedo, with launching apparatus and other appendages complete?

TORPEDO EXPERIMENTS AT PORTSMOUTH, ENGLAND.

In September, October, and November, 1886, some torpedo experiments were carried on against the Resistance, to test the efficiency of net protection, and the destructive effect of gun-cotton on an iron hull not so protected.

The Resistance was launched in 1861, and was constructed on a different system from that now in vogue. Her load displacement is 6,270 tons, being a little less at the time of the experiment; armor 4½ inches thick in a belt from 4 feet under water to the spar deck; frames spaced 2 feet; skin plating ⅝-inch iron; no double bottom.

The first experiment on September 21 was in the explosion of 61 pounds of gun-cotton against a Bullivant net hung at 30 feet from the side; it resulted in the tearing of the net, the swifter, however, being left intact and the booms uninjured, though the heel of one was unshipped.

The next day a 16-inch Whitehead, carrying 91 pounds of gun-cotton, was fired against the net hung in the same position, with the result of tearing away nearly the whole of the net and splitting one boom about the middle.

In the third experiment the net was only 15 feet from the ship's side, and a charge of 61 pounds of gun-cotton was exploded in contact; a sea-cock was broken by the concussion, causing a leak.

On October 18 another 16-inch Whitehead was fired, its charge of 91 pounds exploding on impact with the net, which was hung at 25 feet from the side. A rent of 15 feet was torn the entire depth of the net and the swifter broken, but the hull sustained no injury.

The concluding experiment, on November 2, was against the hull itself. The point selected for attack was on the port side abreast a coal-bunker 4 feet 7 inches deep. This was filled with coal and a ½-inch longitudinal water-tight bulkhead was worked 5 feet inside of it, forming a second compartment 5 feet deep. A torpedo-head holding 91 pounds of gun-cotton (wet) was placed in contact and with its axis normal to the hull, 10 feet under water, just at a half-inch thwartship bulkhead and just below one of the numerous longitudinal stringers. At the time of the experiment there was about 6 feet of water under the keel. The ship gave a moderate lurch to starboard, and finally remained fixed with a slight list to port. She did not sink, and was not even docked for several days afterwards.

The effect of the concussion was distributed over an area of about 20 feet in length by 15 in depth, the limits in the latter direction being the armor shelf and the outer bilge-keel. Throughout this surface the skin was bulged in between the frames, none of the latter being broken excepting the two nearest to the point of explosion. Here the longitudinal had been forced in and the metal of the skin torn apart; five plates were slightly cracked vertically. The thwartship bulkhead was considerably torn and rolled up, and the coal-bunker bulkhead was torn with it, admitting water to the inner compartment; but the third skin was intact. The outer bilge keel was started and bent downward and broken in places for about 8 feet. The interior of the vessel gave evidences of a great concussion; bunker plates had been thrown up and struck the deck above; deck stanchions had been lifted in their seats, fire-room plates displaced, skylights unseated, and a signal mast broken off just below the hounds. There being no steam up nor any engines in motion the effect on running machinery was not determined. As it was, the force of the blast was mainly expended in local disruption, and, apart from the moral effect, which it would be difficult to predicate, the fighting efficiency of the ship was not seriously impaired.

There is a discrepancy difficult to account for in the results of this trial and of others in previous years. At the first blush it would now appear that the destructive power of the charge carried by the present type of fish torpedo has been overestimated, and that a vessel is not liable to be crippled by such attack. On the other hand, everything seems to have been arranged in this case to give the ship the advantage, and service conditions might be less favorable.

As regards the structure of the hull, the frames were spaced only 2 feet instead of 4, as is more usual now; the explosion took place at just about the turn of the bilge and at a point particularly well supported by a thwartship bulkhead and strong longitudinals. Whether or not the effort would have been less generally destructive had the outer compartment been empty and the inner filled is a question; but it does seem possible that with a moderately thick steel skin, and with extensive water-tight subdivision, a large ship may be made able to stand a limited number of such blows if not delivered well below the turn of the bilge nor too near the propellers or shafts.*

TORPEDO EXPERIMENTS AT TOULON.

In September, 1886, at Toulon, 110-pound charges of dry gun-cotton were detonated at different distances from the side of the Belliqueuse an old wooden iron-clad, to test the efficiency of net protection. At 9 and 8 metres distance no damage was done to the hull; at 7 metres the calking was driven out of a seam for a length of about 6 feet, but that was presumably due to defective calking, as at 6 and 5 metres no effect was produced.

BERDAN.

General Berdan has devised a system of torpedo attack by boats upon net-protected vessels. For description see page 5.

WHITEHEAD.

The Whitehead continues to be the only type of fish torpedo in general use, the name being intended to include all the various patterns that spring from that origin. A speed of 27 knots has been realized by some.

Occasional trials, however, have lately tended to throw a little discredit on the performance of this weapon, it being shown that it is deflected under many of the conditions that are apt to obtain in service, and that target practice is usually less accurate than it should be. At Malta, in July 1886, three torpedoes were fired at the Polyphemus while she was advancing directly toward the attacking boat, the latter being securely moored. Not one struck, but it was claimed that the pointing was wild, and the question of their being deflected or not by the bow-wave remained unsettled. Three more were then fired at the same vessel while she was passing at a distance of 200 yards and at a rate of 16 knots; one went ahead, one astern, and one struck abaft the middle.

A new departure was tried on board the Mersey in February, 1887, in the matter of broadside under-water discharging apparatus. The shield and guide-bar were dispensed with; long slits were cut in the skin, the interior space being tapered to the impulse tube to allow the torpedo to be deflected by the pressure of water without endangering the tail. While running at moderate speeds the arrangement appears to have worked satisfactorily; but at 18 knots the torpedoes were badly scored by the friction during ejection, and some were broken up; they also were deflected so as to run aft parallel to the ship, endangering the propellers.

Stern discharge has also been found to labor under serious disadvantages. In the Rattlesnake, in April 1887, torpedoes falling into the broken, whirling water from the twin screws are said to have been very erratic in their movements; when fired off the quarter they made fairly good runs, but no dependence could apparently be placed upon them when discharged right astern.

A further grave matter touching the efficiency of the Whiteheads has recently been brought out. When the French torpedo-boats reached Toulon from Brest, in March, 1887, it was found that the delicate adjustments necessary for the preservation of a straight course had been so affected by the incessant rolling and tossing of the boat at sea, that the trajectories of the torpedoes made angles up to 15°, in a horizontal plane, with the intended path. This does not apply to the weapons on board ships, but is all the more serious in boats from the fact that the adjustments can neither be verified nor rectified by any means at command.

---

* An account of the Resistance Torpedo Experiments in June, 1887, will be found in the Addendum, p. 346.

HOWELL.

The Howell torpedo bids fair to soon gain professional favor. Its initial speed is now 23 knots for the 8-foot pattern, weighing 325 pounds, including 70 pounds of explosive. A description of the torpedo and of an improved discharging apparatus will be found on page 23.

LAY.

Mr. John L. Lay has recently produced an "Improved Lay" torpedo in England, of which a description will be found on page 33. Several novel features in its design will attract attention, and it seems fair to expect that the causes of the mishap attending its trial will be speedily remedied.

PATRICK.

During the past year there have been several trials of the Patrick torpedo in the United States, before Turkish, French, and Japanese naval boards, and officers of the United States Navy. On each occasion the expected results were attained, both as regards speed and control. For description and trial, see page 35.

SIMS-EDISON.

The Sims-Edison Company have continued to furnish 2-mile torpedoes to the United States Army. For description of this torpedo, see page 41.

BRENNAN.

The Brennan torpedo has been acquired by the British war office under circumstances that indicate a high confidence in its merits as perfected. The salient features of the design are given on page 43.

TORPEDO NETS.

Steel nets continue to be an increasing factor in protecting vessels from torpedo attack; appliances for fitting and rigging them have been greatly improved, and a a saving effected in the time required for handling them.

As will have been noticed in two of the attacks on the Resistance (see page 333), a 16-inch Whitehead which was fired against the net exploded without getting through; it was of an old pattern, however, and slow. At Toulon five of more recent construction have been sent against netting, all of which exploded on striking; then a charged head was detonated in contact with a net, making a hole in it and breaking one spar, but two Whiteheads fired at the hole immediately afterwards were exploded by the remaining débris, and others, not fused, were stopped by it.

In the attack of ports, or as a precaution while at anchor or blockading, it is probable that all heavy ships will be fitted with them; but in actions at sea many other considerations have to be taken into account. The speed of the vessel has to be materially reduced; nets have been down while going 7½ to 8½ knots, but they sag aft and up very considerably when dragged at that rate, and, particularly with any sea running, it is probable that a still slower speed may prove advisable, even if only carrying broadside nets. The verdict of recent experiments with French vessels seems to be that the nets are efficacious when the speed is not over 5 knots. They do not appear to affect the manœuvring of a vessel, but an enforced maximum speed of 6 or 8 knots would lay a ship dangerously open to a ramming attack, especially as she could not use her own torpedoes. The weight and space of a complete net defense will also preclude its being fitted to any but moderately large vessels.

In the Bullivant nets, which are in general use, the wire grommets are about 6 inches in interior diameter, connected by smaller rings. As the speed and momentum of the Whitehead has increased, it has been considered necessary to increase the strength (and weight) of the nets; the weight of one 15 feet on the head and 20 feet deep varies from 250 to 420 pounds, according to the strength required in the order, not including the shackles on the head and leeches, nor the chain along the foot.

Wooden booms have been in more general use so far, but the lightness and mechanical fittings of the steel ones, such as designed by Bullivant, are a powerful inducement to change. These are 32 feet long, carrying the nets at 29 feet from the hull and the steel anti-torpedo-boat hawser at the ends. The topping-lifts, guys, outhauls, inhauls, and brails are of flexible steel wire rope. The lifts have to lead at a small angle generally, so as not to interfere with the gun fire, which they would do if taken high up.

The use of metallic outriggers, with their travelers, greatly facilitates and expedites the operation of rigging and sending out the nets. Heretofore it has been the frequent practice to use the ship's boats for lacing or shackling on to the swifter, it being more quickly done in that way than from on board with the wooden booms in the securing position; that method is objectionable on many accounts, and impossible in rough weather.

The possibility is contemplated of having to fit two lines of net defense to ships, the additional one being at 15 to 20 feet from the side. The causes that would possibly lead to such a measure would be the production of a torpedo that could break a way for itself through the first net by means of a secondary charge of explosive or otherwise, leaving the main charge ready to act on the hull.

SEATON SCHROEDER,
Lieutenant, U. S. Navy.

TORPEDO-BOATS.

Swayed by the concurrent testimony of different officers who conducted or took part in the naval manœuvres of 1886, professional opinion appears to accept the verdict that torpedo-boats are very delicate instruments at best, and that a greater tonnage is imperative where service at sea is anticipated. A day or two in even moderate weather is sufficient to exhaust the staunchest crew on account of the constant, excessive balloting about, and a prolonged voyage has been found to be fatally injurious to the adjustments of the Whitehead for horizontal accuracy. Furthermore, in such small, low craft, a correct estimate of the distance, speed, or course of the enemy is most difficult, especially if the officer be in the conning tower, looking through the narrow sight-slits; in anything of a sea way, also, accurate pointing is out of the question.

The impotence of a boat fitted with only bow tubes was emphasized in an attack made on the Richelieu off Toulon in October, 1886. There was a moderate breeze and sea from northwest; the Richelieu, with her nets down, maintained a speed of about 4 knots, while torpedo-boat No. 26 (108 feet long, 45 tons displacement) manœuvred to attack. Although the circumstances were not especially unfavorable, the boat's bow tubes were constantly submerged when head to sea, and she had finally to be given an opportunity of discharging her torpedo to leeward; this was done at a distance of 200 metres, and the target, 322 feet long, was missed, owing, it is said, to the boat making a sheer at the moment of firing.

It is said that the French naval authorities at Toulon have succeeded in devising an efficient tube-closer, which is shot away with the torpedo, and by which, therefore, the tube may be kept closed in action.

This difficulty in obtaining bow-torpedo fire has otherwise been obviated in a design of Mr. Normand, in which the tubes, still remaining parallel to the middle line, are brought aft to abreast the conning tower, one on either side, and raised. The direct fire ahead is thus effected in much the same way as gun-fire from the sponsoned half-turrets of larger vessels.

In the course of the past year Schichau has yielded to Thornycroft the honor of producing the fastest vessel in the world, the owner now being the Spanish admiralty in place of the Russian. The boat thus distinguished is the Ariete; speed 26.18 knots.

It has become a question in the minds of some eminent designers and observers, notably Mr. Normand, whether or not the extreme speeds sought and obtained in some recent boats are not excessive. Damage to the motive machinery is more to be apprehended than any injury to the hull or casualty among the crew; when it is considered that under ordinary conditions of weather and service the speed of the fastest will be little if any greater than that of an ordinary 20-knot boat, the propriety at once suggests itself of devoting to steel plate the extra weight of boiler, water, and engine necessary to produce that practically superfluous horse-power.

AUSTRIA.

The Habicht, a 90-ton boat, built by Schichau for the Austrian navy, made 21.77 knots for three hours, or 1¼ more than required by contract. It is understood that future torpedo-boats will be much larger, approaching 300 to 400 tons displacement. The naval budget for 1887 provides 720,000 florins for torpedo boats and vessels.

CHINA.

A 128-foot boat built by Yarrow for China made 23.88 knots on the measured mile, and averaged 22.94 for two hours, carrying full equipment and complete weight of armament, but not quite full supply of coal. Her displacement is 69 tons; triple-expansion engines; locomotive boilers; diameter of turning circle less than two lengths.

A large boat built by Schichau, 144 feet 4 inches long, 16 feet 5 inches beam, 7 feet 6½ inches draught, steamed from Elbing to Foochow in the fall of 1886, arriving in good condition. On trial in the Baltic she made 24.23 knots for one hour, carrying coal for 1,000 knots. With coal for 3,000 miles an average of 22.5 was maintained for four hours.

ENGLAND.

In England a change of policy has been decided upon in the matter of torpedo-boats; those for service in the open sea will be much larger, of the Rattlesnake type, carrying rapid-fire guns and one of heavier calibre. A new type of second-class boat has been adopted, capable of being hoisted on board ships of a certain displacement, to replace the 125-foot boats which had been intended to accompany the squadrons. The 125-foot boats have been allotted to the defense of ports and coaling stations; twenty-five of them are to have the bow-tubes removed and the snout cut off, leaving a straight stem, their performance in a sea-way being found moro satisfactory with that alteration.

One of the 125-foot Thornycrofts, in September, 1886, averaged 22.34 for an 80-mile run, 40 miles down the Solent and into the Channel, and return.

A speed of 22½ knots has been maintained for several hours by both Yarrow and Thornycroft boats of this size, 23 knots being attained for short runs. No. 79, a 128-foot Yarrow, in six runs over the measured mile in December, 1886, averaged 22.39 knots on a displacement of 70 tons, the engines making 401 revolutions with 140 pounds boiler pressure and 26 inches vacuum. The diameters of turning circles were: going ahead, to port 80 yards in 59 seconds, and to starboard 90 yards in 57 seconds; going astern, to port 70 yards in 70 seconds, and to starboard 60 yards in 60 seconds. There is no forward rudder, but the after one extends below and forward of the stern-post. In turning, the boat pivots well forward and heels inwardly a little.

A 135-foot boat recently completed by Yarrow made an average speed of 23 knots for six runs over the measured mile. The beam is 14 feet; displacement on trial 102 tons, 15 tons 8 cwt. being weight carried. The coal capacity is 35 tons, being enough for 2,500 knots at 10 knots. One boiler supplies steam to triple expansion engines, developing about 1,600 I. H. P. All the machinery is surrounded by coal. There are 10 water-tight compartments, each having pumps and ejectors of 40 to 80 tons capacity. Yarrow's water-tight ashpan arrangement is also fitted; the furnace will hold one ton of coal, which will raise steam for eight hours at 10 knots. There is one torpedo-tube forward, and around the after conning tower a pair of tubes revolve which can discharge at considerable angles forward and aft. Five rapid-fire guns are provided. The average time of turning ahead was 1 minute 15 seconds; diameter of circle, 120 yards; astern, 2^{m}, 130 yards.

The type of second-class boat selected, offered by Yarrow, is similar to No. 79, but smaller; two sizes will be built, one weighing 15 tons to make 17 knots, and the other weighing 13 tons to make 16 knots.

FRANCE.

The evolutions of 1886 convinced the French naval authorities that the 33-metre type of torpedo boat, while efficient for harbor defense, is too small to be considered as an "autonomous" sea-going craft. The consequent policy is to build larger ones.

Furthermore, Admiral Aube, the minister of marine, has taken into consideration the project of torpedo supply vessels on a greater scale than has been the case in other admiralties. The plan is apparently to build for this purpose three coast-defense vessels to carry a belt of 14 inches of armor, a 2¾-inch protective deck and a central redoubt with 12 inches of armor, to have a battery of two 13½-inch guns besides revolving and rapid-fire guns and torpedo tubes, and be fitted with torpedo-nets. These vessels are intended to carry a large supply of spare torpedoes, ammunition and coal, and a plant for executing repairs, and each will accompany a division of six torpedo-boats.

Three 134½-foot boats, the Balny, Déroulède, and Doudart de Lagrée, have been completed by Normand. They carry two tubes forward and two 37-millimetre H. R. C. The machinery comprises independent air, feed, and circulating pumps, the latter having to be started only when the boat is at rest, as, when under way, the condenser surfaces are cooled by the passing water. The maximum trial speed was 20 knots; when loaded they made 19 knots. The coal endurance is about 1,300 miles at 12½ knots, and they carry two canvas collapsible boats, one on deck and one below. In the quarters canvas is stretched a short distance from the skin to form an air-space, but this is said not to be efficacious in reducing the heat. They behave satisfactorily at sea, being a great improvement on the 108-foot boats, but still do not appear to be popularly considered as "torpilleurs de haute mer." Six more of the same class are in various stages of construction in different yards.

The first of the 35-metre type (114¾ feet) was launched in January, 1887, and the recent naval budget provides for 24 more first-class boats, which will not be begun, however, until those now building are tried. Money was also voted to build eight of the Ouragan type, which will not be begun either until after her trials.

The Ouragan, laid down in the summer of 1886, is spoken of as a "contre torpilleur," on account of her increased size and the armament of two 47-millimetre H. R. C., which she is to carry. She was designed by the "Ateliers et Chantiers de la Loire," and built by the same company, at Nantes, as a speculation, the Minister of Marine afterwards agreeing to purchase her if the expectations and promises of the company were realized. The principal dimensions are: Length, 151 feet; beam, 15 feet 9 inches; draught, 8 feet 4 inches; displacement, 148 tons. The speed is expected to be 25 knots; the contract calls for 22, with a premium for excess, and the stipulation is made that the boat shall go from Nantes to Toulon without stopping. There are two locomotive boilers, supplying steam to a single 4-cylinder engine which works with quadruple expansion at ordinary speeds and triple expansion for full power. The torpedo armament consists of two tubes forward, 5½ feet above water, and two on deck each on a movable carriage which can be run on tracks from side to side; as the sides do not tumble home, the latter can be trained well forward and aft.

The "Forges et Chantiers," La Seyne, have built some very successful vedette torpedo launches, 41 ft. long, 7 ft. 5 in. broad, 3 ft. 7 in. draught, displacing 7 tons. They have made a speed of 14.18 knots over the measured mile; the average for three hours was 12 knots.

GERMANY.

Among the German torpedo-boats, those built by Schichau are most highly spoken of, on account of their sea-worthiness, speed, and economy; greater beam in proportion to length, coupled with the ability to run the engines at greatly reduced speed, contributed to their good behavior in a sea-way, the speed being made up by greater engine-power. They also have straight stems and do not carry such a big *bone* as those of many other builders in different countries, and can consequently fire the bow tubes with greater safety and precision.

The two 220-ton "division torpedo-boats" have been completed; they are 185.3 feet long, 21.6 feet in beam, with 9.8 feet draught. They are to be fitted with tubes like the 90-ton boats, but their main work will be to form a movable base for a division, being roomy and provided with a plant for making repairs, also medical facilities, and spare men, torpedoes, and gear. Their armament will be six 37-millimetre H. R. C.

ITALY.

The four 90-ton Schichau boats built for the Italian admiralty have been delivered, having exceeded the contract speed (21 knots) by 1½ knots. One of them collided with her consort and sank off the Spanish coast while on their way to the Mediterranean.

The two 140-foot twin-screw boats built by Yarrow have been completed and tried, one averaging 24.964 knots for six runs over the measured mile, and the other 25.1 knots, the greatest speed that had been attained by any vessel up to that time. Their beam is 14 feet, draught 5 feet 4 inches, displacement 100 tons. They have two locomotive boilers, one forward of and the other abaft the engine-room, both of which can furnish steam to either or both engines, which are compound. The centrifugal circulating pumps can draw from any compartment, besides which there are ejectors and hand pumps for each compartment. There are ten water-tight bulkheads, and Yarrow's patent arrangement is fitted for preventing the fires being extinguished by water rising in the fire-room. (See Gen. Inf., Series No. V, p. 127.)

Double steam steering gear is fitted to work the forward and after rudders independently of each other. The torpedo armament consists of two torpedo tubes forward in line with the keel, and four on two turn-tables, those of each pair making a small angle with each other to increase the chances of a hit in firing both together; two 3-pounder rapid fire Norfeldts are also provided, and a search light.

JAPAN.

A large twin-screw Yarrow boat, 166 feet long, 19 feet broad, has been completed and shipped in sections to Japan. She has two boilers which, with the engines, are protected by 1-inch steel armor. There are six torpedo-tubes, two forward in line with keel, and the rest in pairs on turn-tables, those of each pair forming a slight angle with each other. Four machine-guns are also provided. The speed is said to be 19 to 20 knots.

RUSSIA.

The nine 90-tonners ordered of Schichau for the Russian Government in December, 1885, were completed in the summer of 1886, and proved highly successful in point of speed, endurance, and seaworthiness. Their length is 125 feet, draught 11½ feet when loaded to the full 90 tons displacement. On the trials, on about 85 tons displacement, all made over 21 knots, all but one made over 22, and several made 23 knots an hour. They have five complete bulkheads and one half-bulkhead forward, a 14-ton ejector in each compartment, and steam steering gear to work forward or after rudder independently. The armament consists of two tubes forward in line with the keel, dipping downward 2½ degrees, and four 37-millimetres R. C. One steel and one canvas boat are carried.

Normand has built two 100-ton 154-foot boats for Russia, the Sweaborg and Revel. The latter averaged 22 knots at the trials.

The Wiborg, built by J. & G. Thomson, completed her trials in October, 1886. This is a twin-screw boat, 142 feet long on the water-line, 17 feet beam, load displacement 167 tons. The hull is very much rounded above water, and has a long sloping bow covered with ½-inch plating. There are 23 water-tight compartments, and forward, in the vicinity of the water-line, there is an inner skin leaving a cellular space that can be filled with water-excluding material. The ten ejectors can discharge

1,500 tons in one hour, and the centrifugal circulating pumps will draw 300 more. The engines are vertical compound, supplied with steam from two boilers, each of the latter being in a separate compartment, and the whole being surrounded by protective coal. Steam starting gear is fitted to insure rapid reversal of the engines. The bunkers hold 45 tons, which will last for 4,000 miles at 10 knots. The armament consists of two 47-millimetre revolving cannon and six 19-foot torpedoes, which will be fired from two tubes forward and one revolving amidships. The interior is lighted by incandescent lamps, and a 12,000 candle search-light is fitted on the conning tower. The following mean speeds were realized in 3-hour trials: Displacement 131 tons (carrying 34 tons), speed 20.6; displacement 138, speed 19.96; with load displacement of 167 tons, ready for sea, speed 18.55; with one screw going and one dragging 17 knots was made; with both engines and one boiler, 17½ knots; full speed astern 16 knots.

SPAIN.

Spain has now the fastest torpedo-boat in the world, a speed of 26.18 knots having been attained in the trials of the Ariete, a 147½-foot boat built by Thornycroft. Another of this size is in course of construction, to be named the Rayo; they have 14½ feet beam and 4 feet 9 inches draught, and are propelled by twin screws; the armament consists of two torpedo-tubes and four machine-guns. Yarrow has two boats in hand, the Halcon and Azor, 134½ feet long, 14 feet beam, to make over 23 knots and to carry the same armament as the Thornycrofts.

The Julian Ordoñez and the Acevedo have been completed by Thornycroft; length, 120 feet; draught, 5 feet 11 inches. They are said not to have realized at Ferrol the guaranteed speed which they developed on the Thames.

TURKEY.

The Turkish admiralty patronizes all markets for torpedo-boats, including its own dockyards. At Constantinople there are building four boats, 100 feet 4 inches long, 11 feet 9 inches beam, to make 19½ knots; also a 140-foot boat, 16 feet broad, 6 feet 10 inches draught, 110 tons displacement, to make 23 knots.

The Germania Company, of Stettin, have in hand nine boats, 121 feet 4 inches long, to make 22 knots.

A 126-foot boat has been completed by Maudslay Sons & Field; it has 15 feet beam, and averaged 21.7 knots at the trials, the maximum being 23.4.

UNITED STATES.

On the 1st of July, 1887, the United States will own a torpedo-boat, the Stiletto. A general description of this remarkable little vessel will be found in Gen. Inf. Series No. V, page 134. Her load displacement is 35.65 tons, of which 9.2 tons are weight carried. After deducting for 10 men, 1 boat, 2 tubes, 3 torpedoes, a 37-millimetre H. R. C., and 600 rounds for it, there would be left 4 tons for coal; 3 more tons will only bring her down 2 inches more, and the total, 7 tons, will carry her about 300 miles at 19 knots. The hull is divided into six water-tight compartments, from all of which, except the two end ones, water can be drawn by an ejector.

On July 3, 1886, six runs were made over the measured knot, on a displacement of about 28 tons, the wind being fresh and the water rough. The true mean of the six runs was 22.898 knots, which exceeds any speed ever attained by a boat of that size. During another trial, six half-circles were made, the average time being 41 seconds to starboard and 47 seconds to port. The heel was not great in turning.

The essential features of the Stiletto, regarded as a torpedo-boat, may be summed up as follows: Being built with a wooden skin, she is not heated up to such an intense degree as the steel boats, and less water would enter through machine-gun shot-holes; the economy is great, and the speed satisfactory and well-sustained; the firemen can easily escape from the closed fire-room; the type of boiler (Herreshoff coil) is good, as the amount of steam to escape, if penetrated, is small, while it can be forced to any extent.

NORDENFELT SUBMARINE BOAT.

The "Nordenfelt," a submarine torpedo-boat, launched in March, 1887, at the Barrow Ship-Building Company's Works, is the largest and most powerful ever yet constructed. The length is 123 feet; beam, 12 feet; depth, a little over 12 feet; displacement wholly immersed, 243 tons. The upper part of the turtle-back is plated with one-inch steel, as are also the two conning towers. Steam at 150 pounds pressure is supplied by two large multitubular boilers to two pairs of compound engines driving a four-throw crank-shaft and single screw. There are also other engines for sinking, steering, circulating, pumping, driving fans, &c. The general principles upon which the boat is manœuvred are the same as in Nordenfelt's previous models, described in General Information Series No. IV. The reservoirs and boilers hold enough superheated steam and water to propel the boat 20 miles with the fires out. The ordinary coal capacity is 8 tons, which will drive her 1,000 miles at 8 knots; 20 tons can also be stowed in the three cold-water ballast-tanks. In a recent preliminary trial, a speed of 6 to 8 knots was attained with fires out and only the two turrets showing; with a less displacement, and steam up, she made about 13 or 14 knots. There is an apparatus by which the speed of the two vertically-placed screws which pull the boat down under water, may be increased or decreased independently, to keep her in a horizontal position. The offensive power is vested in two tubes and four fish torpedoes, and for defense she will carry two Nordenfelt guns.

SEATON SCHROEDER,
Lieutenant, U. S. Navy.

ELECTRIC LIGHTING.

ELECTRIC LIGHTING IN THE FRENCH NAVY, 1887.

(Translation of a pamphlet issued by Sautter Lemonnier & Cie., Paris, entitled "The Electric-Lighting Plant of the French armor-clad Indomptable," forwarded from the office of the Naval Inspector of Electric-Lighting.)

General observations.—The main objects in the electric-lighting plant destined for the armor-clad Indomptable, are the reduction of velocity in the motors which control the dynamos, in order to dispense with special motors, such as the Brotherhood and Mégy, and to substitute for them vertical motors of a type common in the navy. These objects, partly attained on board of the Japanese cruiser Unebi, but in an experimental manner, are set forth in a note drawn up at the time of the trial of the apparatus in the latter part of last June, as follows:

The use of electricity on board of naval ships and merchant steamers is rapidly changing and developing. It is already long since a small dynamo of 20 to 30 ampères, controlled by a Brotherhood engine, was considered a curiosity, and occasionally used for a search light or a light at the mast-head. There are now no war vessels without interior and exterior electric lights, and no passenger steamers without a greater or less number of electric lights in saloons, state-rooms, and engine-rooms, and arc lights, with or without projectors, for entering and leaving port or passing through the Suez Canal.

The electric installation on board of the latest transatlantic steamers is computed at 100 horse-power, and 60 or 70 horse-power should be allowed for the total illumination of an armor clad. (These figures include duplicates.)

It is easy to predict further applications of the electrie current. The transmission of power to a distance already offers its resources to the navy, and, before long the horse-power reckoned above will be insufficient.

General characteristics of the apparatus.—However this may be, for the present the fact that it is necessary for ship service to produce electricity continuously, and with steam engines of a certain power, has led us gradually to look for economical engines, viz, those that are simple, use a small amount of steam, and are not dissimilar to the types commonly used in the navy. This last condition is of great importance in the merchant service, where the force of skilled mechanics is small and expensive.

These conditions set aside engines of 15 or 20 horse-power that make more than 400 revolutions a minute.

On the other hand, as the navy did not wish to give up its customary method of controlling dynamos without the use of gearing, belts or ropes, and as the merchant marine was anxious to get rid of the latter method, the difficulty was to find dynamos powerful enough with a sufficiently low speed. The other exigencies of sea service must be considered also, such as limitations of weight and space and an apparatus normally working very much below its effective power.

Having nothing material to change in these general observations, we have been careful to profit by the detailed criticisms which have been made during the past six months, especially in facilitating the taking apart of the engines.

Detailed description of the plant of the Indomptable.—Each of the two plants should give normally from 150 to 160 ampères and 66 volts, with a speed not exceeding 350 revolutions per minute.

The dimensions of the plant are, length, 3.40^m = 11.1 feet; breadth, 0.80^m = 2.6 feet; height, 1.60^m = 5.2 feet; weight, 3,200 kilograms = 7,040 pounds.

Dynamo.—The gramme dynamo employed is of the multiplex type—that is to say, one having several pairs of magnetic poles; this particular one is of the duplex pattern with two pairs of poles. The induction differs only from the ordinary gramme in the exactness of its construction, and that the sections are coupled by twos. This induction takes place in a double magnetic field whence the name duplex given to the dynamo. Each of these two magnetic fields acts on the part of the armature which crosses it, to produce a current independently of a simultaneous action of the other magnetic field. The result is, that with the same velocity, the duplex dynamo will give double the number of ampères, with the same electro-motive force, when compared with an ordinary gramme dynamo with its armature revolving in a magnetic field of the same intensity. Or the duplex dynamo will give the same number of ampères and the same electro-motive force at half the speed of the ordinary gramme dynamo.

Thus the desired object is obtained without an increase of weight. The duplex dynamo is in fact, on account of the construction of its electro magnets, lighter than an ordinary dynamo of the same power with double the velocity.

The cast-iron frame work, which is a large factor in the weight of the ordinary gramme dynamo, is not used in the duplex dynamo.

The magnetic field is formed in the simplest manner by a continuous chain of four electro-magnets with cases of soft iron meeting and closing one upon the other.

These electro-magnets are doubly wound. The fine wire carries the current from a shunt circuit, and the large wire is in series with the outside circuit [compound-wound.—TRANSLATOR].

The collectors are of large diameter, and the position of the brushes is regulated with great precision and facility by means of a clamp and tangent screw.

The dynamo is magnetically insulated from its cast-iron base by two brass supports.

Finally, special facilities are afforded for taking it apart. All the upper part of the dynamo can be taken off in such a manner as to permit the armature to be replaced in a few moments.

This dynamo, with an armature velocity of 350 turns a minute and a constant potential of 66 volts, can vary its current from 1 to 150 ampères, and operate from 1 to 225 10 candle-power lamps, the power employed varying according to the number of lamps in operation. We will add that the excellent results obtained at the trial on board the Unebi have been fully confirmed by later installations.

Steam-engine.—The engine is of the vertical compound type, with two cylinders. It can be operated at will as a high-pressure or as a condensing engine. It is normally of 20 effective horse-power (French), with a pressure of 3 kilograms (42.6 pounds per square inch). In order to reduce the weight to a minimum the cylinders and framework only are of cast iron, all other parts being of bronze or steel. An examination of the drawing shows that all parts are in full view and quite accessible when running. All of the bearings are of phosphor bronze, and covered with anti-friction metal. Steam is admitted to the large cylinder by a single valve and to the small cylinder by a double valve with a variable motion; in this manner, with a suitable governor, the engine can always run with an economical use of steam either with a vacuum or atmospheric exhaust. The governor is particularly sensitive, and so arranged that the normal speed can be varied while running. Careful arrangements have been made for oiling all parts.

Coupling.—The engine and dynamo are placed in line, on a common iron bed, resting on I-beams, which also serves as a base for the various parts of the dynamo. The coupling is made by a flexible joint, thus dispensing entirely with the minute precautions necessary to preserve an exact alignment.

Normal capacity.—One of these plants is a suitable unit for the installation of electric lights on board of men-of-war, cruisers, or armor-clads. It can supply either two hundred and twenty-five incandescent lamps of 10 candle-power, or four projectors of 1,600 *becs* (= 15,200 candle-power), or eight projectors of 500 *becs* (= 4,750 candle-power), with the ability of substituting a projector of 1,600 *becs* for sixty lamps of 10 candle-power, or one of 500 *becs* for thirty lamps of 10 candle-power.

Lights on board of naval ships.—It will be observed that in constructing these plants we are trying to fill a want recently experienced in the Mediterranean, viz, the protection of vessels against the attacks of torpedo-boats by a continuous belt of light. To meet this want it is necessary to add to the projectors of great intensity and carrying power others less powerful but more numerous, and with large horizontal divergence. For this reason the Danish Government recently installed the cruiser Ivert (Iver Hvitfeldt) with eight projectors of 40 centimetres, each having a divergence of 90°.

One of the plants of the Indomptable can feed or supply eight projectors of 40 centimetres with 45° divergence—that is to say, the entire horizon—while the other can operate the two hundred and twenty-five inside lamps. Being identical, one can be used for either of these different services.

The trial of these steam-engines indicates the consumption of at least 9.5 kilograms of water per hour per effective horse-power, the latter measured by a dynamometer. Pressure of steam, 3 kilograms (42.6 pounds per square inch); condensation, 0.60 (24 inches vacuum).

ADDENDUM.

TORPEDO EXPERIMENTS AT PORTSMOUTH, ENGLAND, JUNE, 1887.

Torpedo experiments against the Resistance were resumed on June 9, 1887, and the following is summarized from accounts in the London Times of June 10, 11, and 14:

The vessel was fitted with Bullivant nets and 32-foot steel booms, the latter being spaced 45 feet. The wing passage was left empty, and the coal bunker, which had been worked inside of that, was filled. On the 9th of June an old pattern 16-inch Whitehead, set for 10 feet, was fired against the net on the port side abreast the engine room, from the under-water tube of the Vesuvius, at an approximate range of 50 yards; the charge was said to be reduced to 87 pounds of gun-cotton. The torpedo struck the net in the middle, immediately under a boom; no damage ensued to either boom or hull.

On June 10, a charge of 220 pounds of gun-cotton was suspended at a depth of 20 feet from the jackstay of the nets (which are 20 feet deep), 30 feet from the side. When it was exploded the ship was not observed to heel or move; some of the steel booms were bent, but no other damage was done.

On June 14, a 95-pound charge of gun-cotton was exploded in contact with the starboard bilge, at a depth of 20 feet. The double bottom, 2½ feet deep, was empty, and the coal bunker filled (the conditions being thus reversed from those of last year). The explosion created a sharp, whistling report, in place of the usual dull boom; the ship lifted bodily near the stern, listed gradually to starboard some 8 or 10 degrees, and very slowly sank; coal dust was seen to sweep up from the hold. Accurate knowledge of the result cannot be obtained until the vessel is raised and docked; but from a hasty examination it appears that the inner bottom was dislocated, the bunker compartment was penetrated, water-tight doors and bulkheads had ceased to operate, and water was flowing in from a hundred places.

9.